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A MANUAL

OF

HYGIENE AND SANITATION

BY

SENECA EGBERT, A.M., M.D., Dr. P.H.

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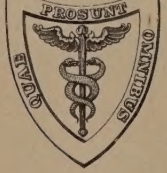
EIGHTH EDITION, ENLARGED AND THOROUGHLY REVISED

ILLUSTRATED WITH 154 ENGRAVINGS AND 4 PLATES



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1926

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1926

TO THE

MEMORY OF MY WIFE,
AND OF MY FATHER AND MOTHER,

TO EACH OF WHOM I OWE SO MUCH; TO WHOM I COULD
REPAY SO LITTLE

THIS VOLUME

IS MOST AFFECTIONATELY

DEDICATED.

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PREFACE TO THE EIGHTH EDITION.

The revision of this work for the present edition has been a more difficult task than heretofore because of the many marked advances that have been made in recent years in almost every division of the science of Hygiene and Sanitation. The past decade has brought new records in the control of disease and the lengthening of the human life-span, but of even greater importance is the growing and general interest in matters of personal welfare and in public health measures that must make the promise of the near future surpass the achievements of the recent past. Consequently, there has been a wealth of material to consider, rich in content of interest and benefit, and the difficulty has been to select and include only such principles and exposition of details as may rightly find place in a manual, and to avoid the temptation to indulge in the wider scope and fuller discussions of a treatise.

One chapter of the previous edition—that on Military Hygiene—has been omitted to make space for two new ones, and the entire book has been most thoroughly revised. The addition of new matter has considerably exceeded the space saved by close pruning and rewriting of other parts of the text. However, the author is again willing to incur the possible criticism of being too conservative in retaining some that is old and in failing to give space to some that is new, for he feels that the importance of well-tried and established principles and data must be paramount in a work such as this.

The chapter on Transmission of Diseases has been inserted to make clear the ways in which infections of various kinds are transferred from one individual to another and the relative importance of the means and modes of transfer. It thus forms a supplement to the preceding chapter which discusses the nature and causes of infection, and leads the way to the consideration of immunity and protective methods in the next chapter.

The other new chapter on Tourist and Vacation Hygiene and Camp Sanitation supplants that on Military Hygiene and deals with matters of immediate interest. The modern conditions that enable many thousands to seek the pleasures and benefits of touring and camping and who in their vacation periods are apt to throw caution to the winds, warrant the introduction of suggestions and advice of practical moment in this respect and may well replace, we believe, the discussion of matters of military preparation and warfare.

In addition to these separate chapters, some discussions of such subjects as Prenatal Hygiene, Habit and Social Hygiene have been introduced in the chapter on Personal Hygiene, together with some of the newer ideas and discoveries relating to the beneficial effects of sun-light and the ultra-violet rays; while in other parts of the book will be found some of the more recent ideas pertaining to hygiene and the importance of living for quality of life as well as additional years, to our knowledge of nutrition as developed by advanced methods of study, etc., etc. The reasons for not adding more have already been given; the inclination and the impulse to do so were strong, but the physical limitations and the character of the book would not permit it.

As the saying is, "much water has run under the bridges" since the publication of the first edition and one only needs to compare a copy of that issue with the present one to appreciate how much the science of Hygiene has developed and advanced during the intervening years. To look for an equal advance in the corresponding period of the immediate future would be almost unreasonable did we not have our experience to strengthen our hope and make us confident that more and better things for the welfare of humanity are yet to come. If this volume may help any to that end, the author will be well repaid; as it is, he is deeply appreciative of the kindly favor and generosity of his readers and critics of the past.

S. E.

PHILADELPHIA, 1926.

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HYGIENE AND SANITATION.

CHAPTER I.

INTRODUCTION.

EVERY intelligent person has some general idea, however indefinite, of the meaning of the terms Hygiene and Sanitation, but the definitions as found in text-books and authoritative writings are many and various. Collectively and inclusively, they may be expressed as the art and science that has to do with the preservation, promotion and improvement of health and the prevention of disease.

One does not go very far, however, in the study of them or in an earnest quest for the principles of good health without finding that the trend of recent years has been to change the relative importance of the two factors, nor without meeting closely related terms, such as Physical Welfare, Public Health, Preventive Medicine Epidemiology, etc., and that these as well as the major subjects require some preliminary definition if confusion of ideas is to be avoided.

The distinction between them is very clearly expressed by Hill,[1] as follows: "Of these terms Physical Welfare is the most comprehensive, since it is the description of the ideal end sought, which end is the securing of high health in the body, and also of the best surroundings for the body. Health is an end also but is a less inclusive

[1] H. W. Hill, The New Hygiene, pp. 12, 13.

term, for it applies to the body only and implies nothing at all about the surroundings. The other terms do not indicate ends in themselves but only various means to the ends, Health and Physical Welfare.

"Hygiene deals with the adjustments which the body may make to its immediate surroundings; Sanitation with the adjustments of these immediate surroundings to the body. Preventive Medicine is a highly technical division of Hygiene, concerned with furnishing the body with certain more or less artificial adjustments designed to protect the body in advance against causes of prospective diseases in the surroundings. Epidemiology is a highly technical division of Sanitation concerned with eliminating prospective causes of disease from the surroundings to the end that preventive adjustments of the body to them may become unnecessary . . . Public Health includes all these subjects as applied to the individual, but deals chiefly with people in the mass rather than as individuals, attempting to secure the highest physical interest of each, but also to harmonize and correlate those interests, sometimes somewhat conflicting, that all persons, not merely a few, may be benefited. It is the sociological division of Physical Welfare.

"The terms listed are by no means only convenient 'subject headings.' They each one indicate a field of activity which is distinctive enough to have its own specialists, its own technicalities, its own methods of study and its own results, as a rule also requiring a special type of mind in its exponents. Thus hygiene is based on physiology, the study of the body; sanitation, on chemistry, engineering, mechanics, physics and other studies of the surroundings of the body; preventive medicine, on medicine, surgery, pathology and bacteriology applied individually to the prevention of disease, and epidemiology on all the foregoing list of sciences and arts as applied sociologically to the prevention of disease. Public health employs all other divisions to the end of securing health and physical welfare."

It must be evident, therefore, that hygiene and sanitation together have much to do with practically all of the physical, and with many of the mental and spiritual phases of life, with the functions and habits of the body, with its growth and development, with the air we breathe and live in, with our food and drink, with clothing and climate, the germs and other causes of disease, with the hazards and stress of occupations and, in fact, with anything that influences our physical welfare for good or evil, for better or worse.

Parkes long ago said that, "taking the word 'Hygiene' in its largest sense, it signifies rules for the perfect culture of mind and body. It is impossible to dissociate the two. The body is affected by every mental or moral action; the mind is profoundly influenced by bodily conditions. (So is the moral conduct of individuals or communities.) For a perfect system of hygiene we must train the body, the intellect, and the moral faculties in a perfect and balanced order." Again, he says: "Looking only to the part of hygiene which concerns the physician, a perfect system of rules of health would be best arranged in an orderly series of this kind. The rules would commence with the regulation of the mother's health while bearing her child, so that the growth of the new being would be as perfect as possible. Then, after birth, the rules (different for each sex at certain times) would embrace three epochs: of growth (including infancy and youth); of maturity, when for many years the body remains apparently stationary; of decay, when, without actual disease, though doubtless in consequence of some chemical changes, molecular feebleness commences in some part or other, forerunning general decay and death. In these several epochs of his life the human being would have to be considered: *First,* in relation to the natural conditions which surround him, and which are essential for life, such as the air he breathes, the water he drinks, etc.; in fact, in relation to nature at large. *Second,* in his social and corporate relations, as a member of a community with certain cus-

toms, trades, etc.; subjected to social and political influences, sexual relations, etc. *Third,* in his capacity as an independent being, having within himself sources of action in thoughts, feelings, desires, personal habits, all of which affect health and which require self-regulation and control. Even now, incomplete as hygiene is, such a work would, if followed, almost change the face of the world."

The foregoing indicates the individual or personal aspect that marked the common concept of the subject until a comparatively short time ago. More recently the tendency is also to view its functions, opportunities and problems from a social and altruistic stand-point, and the field has so enlarged in this direction that the science is no longer so individualistic, but one even more largely concerned with the benefits to humanity at large. Nevertheless, he who works to improve the sanitary condition of his neighbors and his neighborhood, no matter how extensive these may be in numbers and area, at the same time well serves his own interests, for not only is disease no respecter of persons, but its transmission and dissemination depend very much upon one's relationships with others, and a healthy community safeguards the welfare of the individuals composing it.

Before going further it may be well to say that, except where specifically indicated, the term "hygiene" will be used, as it was above by Parkes, more or less inclusively as regards sanitation and the subdivisions already outlined. Moreover, it is well to appreciate that just now we are in a transition stage regarding our conceptions of the real content and scope of the science, and that, as Hill says;[1] "the 'new Hygiene' is truly, at bottom, *the practical study of the potentialities of living protoplasm,*" that it "deals with the reactions of the body to its surroundings," and that it "recognizes the biological fact that life has become what it is today, the most wonderful thing in the world, *by the adjustment of life to things,* rather than by the adjustment of things to life."

[1] The New Hygiene, pp. 2, 4, 5.

For a long time and until comparatively recently the greater stress was laid upon sanitation, that is, upon improving the environment and guarding against its harmful influences and hazards; in other words, in "adjusting things to life." Next came the idea of strengthening the body and increasing its resistance to these harmful influences of the environment, followed by the later and what is probably the more important appreciation of the possibility and high intrinsic benefit of developing a specific resistance against each and every ill that threatens us— of "adjusting life to things."

The student will readily see that the scope of the science is so vast that in a limited work like the present one it would be impossible to go over the entire ground completely and thoroughly. The most that may be attempted will be to discuss its fundamental laws as we now understand them, and to show the reasons for and the advantages resulting from the pursuit of hygienic measures and sanitary methods based on those laws and our experience. Hygiene is, however, a science in the study of which common-sense must be freely used; and if the student will only bring this to his aid and add to it sincere consideration, he will speedily find that there is little that is difficult, beyond his grasp, or less than really fascinating.

It has always been, as it always will be, an art to preserve health and to ward off disease. Hippocrates (400 B.C.) was among the first to define principles of public health or sanitation. He summed up the knowledge of his day concerning hygiene under six headings, viz.: Air, Aliment, Exercise and Rest, Sleep and Wakefulness, Repletion and Evacuation, and the Passions and Affections of the Mind; and he even pointed out that there must be an exact balance between food and exercise, and that "disease would result from excess in either direction."[1]

The excellence of the Mosaic code is acknowledged by all sanitary authorities, and the effects of its observance

[1] Treatise on Airs, Waters, and Places. (About 400 B.C.)

are seen to this day in the comparative longevity of the Hebrew race. Practically all of the important nations of ancient history made physical education an important part of the training of youth, and it is common knowledge that the Greeks cultivated to the extreme both the physical and mental faculties and had for their motto *A sane mind in a sound body.* Recognizing the triune nature of humanity, we shall do well if we include with these the cultivation also of a spiritual health. The Romans, in their aqueducts for conveying water to the city and in the *cloaca maxima*, have left examples of sanitary engineering which are, in certain respects, not yet surpassed. All of which serves to show that the ancients appreciated the importance of maintaining and improving health, and the influence of material conditions and environment upon sanitation.

The development of hygiene as a science, however, has been within comparatively recent years. Perhaps the first great impulse among English-speaking peoples, especially in matters pertaining to sanitation or "State Medicine," can be traced to the labors of Dr. William Farr, and to the establishment, through his efforts, of the British Registrar-General's Office in 1838,[1] followed by the notable and effective achievements of Edwin Chadwick, Sir John Simon and a few others who had the vision and the energy to inaugurate sanitary reforms and practices that led to a complete revolution in living conditions in Great Britain and the practical application of the principles of sanitation there and elsewhere.[2]

[1] Note should be made, however, of the writings of Johannes Petrus Frank, in the first quarter of the nineteenth century and even earlier, and of Parent DuChatelet, between 1820 and 1836. Of the work of the former, it has been said that "It was the first orderly presentation of that which had hitherto been known upon these subjects, and was the first systematic effort to rescue from chaos such useful information as might be of service in the organization of a department of sanitary supervisors, or, as the author preferred to call them, medical police." A. C. Abbott, University Medical Magazine, July, 1900.

[2] A reading of The Sanitary Evolution of London, by Henry Jephson, (A. Wessels Company, 1907), will enable one to realize how far we have advanced within three generations.

Since then the task of determining the principles and laws of health has been carried on with unflagging zeal by workers both here and abroad, and within the last fifty years the knowledge gained in the new study of the bacteria and other microörganisms and their hosts, especially that regarding the causation and nature of infectious diseases, has furnished us with a wealth of facts with and by which we may make the foundations of our science more lasting and secure.

It would be wrong, nevertheless, to give the impression that hygiene is as yet an exact science. While it is rapidly attracting popular notice and attention, and has under the broader and more altruistic development already referred to, attained within comparatively recent years a dignity that it did not hitherto have, there is still much to be discovered or made clear and more to be made practicable and available for the benefit and welfare of humanity. Some of the best minds of the time are busy with many of its problems, and facts and laws are being made clear that more firmly fix or may altogether change some of our beliefs and our practise. Especially is such new knowledge to be sought for in the study of the prevention of disease, the domain of bacteriology and the parasitic diseases, and physiologic and biologic chemistry.

Perhaps a few statistics will help one to realize that the study is not in vain, and that the promise of the future is even more brilliant than the results and achievements of the past. Three centuries ago the death-rate of London was more than 80 per 1000; now it is about 15 per 1000. It is computed that in the eighteenth century—the one preceding the introduction of vaccination—fifty millions of people died in Europe of smallpox alone; now it is almost an extinct disease where vaccination is compulsory, as in Germany. In 1872 Sir John Simon estimated "that the deaths which occur in England are fully a third more numerous than they would be if our existing knowledge of the chief causes of disease were reasonably well applied throughout the

country, and that of deaths which in this sense may be called preventable, the average yearly number in England and Wales is about 120,000." This result was actually more than achieved by 1889, and in 1921 the mortality-

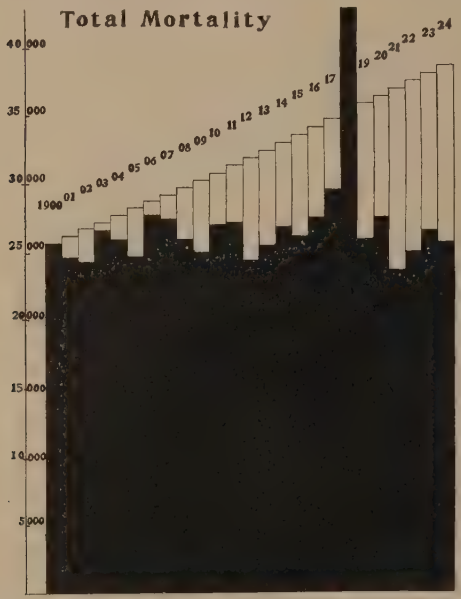


FIG. 1.—Showing number of deaths from all causes in Philadelphia since 1900. The total number would have been larger by more than 132,000 if the annual mortality-rate had remained the same as in that year, the white columns indicating the additional deaths that would have occured in the respective years under the rate of 1900.

rate for these countries had fallen to 12.1 per 1000 of population as compared with an average of 22.6 for the decade 1862–71, this representing a saving of over 350,000 lives in the later year.

In this country a like improvement is to be noted, though it is only within the last few decades that much attention has been given to sanitary affairs. The death-rate of most of our cities is being progressively lowered, though the populations are constantly increased by large numbers of ignorant and uncleanly immigrants. Improved sanitary laws are being enacted and enforced, streets better paved and cared for, houses more wisely constructed and ventilated, more attention given to isolating the sick and protecting the well, and the people in general are awakening to the importance of improving as well as maintaining the public health. New York City (Manhattan Borough) has reduced its death-rate per thousand within thirty years (1890 to 1920) from 25.4 to 14.3; Chicago, from 19.1 to 12.8; Philadelphia, from 20.76 to 14.4; Boston, from 23.4 to 15.4, etc.[1]

Notwithstanding the increase in population, there were over 14,000 fewer deaths in New York City (Manhattan Borough) in 1921 than in 1891, although the increase in population during this period was over 30 per cent., or one-half million of additional citizens. Similar encouraging, if not so striking, reports from many other cities enable their authorities to attribute the good results to advance in medical and surgical knowledge along the lines of preventive medicine, improved sanitary surroundings, better water-supplies, cleaner streets, inspection of milk- and food-supplies, isolation and modern treatment of infectious diseases, additional public parks, etc.

Other evidences of the benefits resulting from the application of the principles of modern hygiene are the marked reduction in the sick- and death-rates due to infectious diseases, and the gradual increase in the average expectation of life in those countries or places where systematic prophylactic and sanitary work is being done. Thus, in

[1] The importance of such statistics is not fully appreciated unless the reader remembers that in a city of, say, a million inhabitants a reduction of the death-rate by one point means the saving of one thousand lives annually.

the so-called "registration-area" of the United States the death-rate for diphtheria has dropped from 70.1 per 100,000 of population in 1890 to 14.6 in 1922; that of malarial fever, from 22.1 to 3.6; of typhoid fever, from

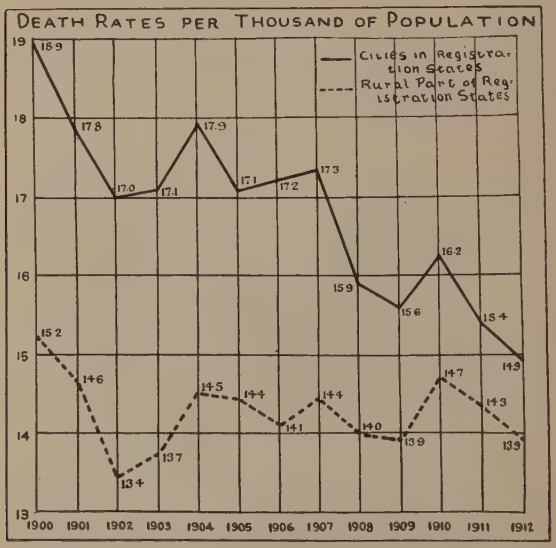


FIG. 2.—A comparison of urban and rural mortality (in registration states as constituted in 1900) from all causes.

COMPARATIVE DECLINE IN URBAN AND RURAL MORTALITY (IN REGISTRATION STATES AS CONSTITUTED IN 1900) FROM ALL CAUSES.

	—Death-rates per 1000 of population.—						Decline in death-rate.	
	1900.	1905.	1910.	1912.	Av'ge '01–'05.	Av'ge '05–'09.	'12 from '00. Actual.	Pct.
Registration states .	17.2	15.9	15.6	14.6	15.9	15.5	2.6	15.1
Rural part of registration states . . .	15.2	14.4	14.7	13.9	14.1	14.2	1.3	8.5
Cities in registration states	18.9	17.1	16.2	14.9	17.4	16.4	4.0	21.2

46.3 to 7.0, and of tuberculosis, from 245.4 to 86.3, while the general death-rate of the same "area" has fallen in the same period of time from 19.6 to 11.8 per 1000 of population.[1]

Likewise, the average duration of life, according to high authority, is rapidly increasing. The rate of increase in Europe "during the latter half of the nineteenth century was about seventeen years per century, and in Germany, where medical and sanitary science had reached the highest development, about twenty-seven years per century,"[2] but there is good reason to believe that at present the gain in this country is even greater, the statement being recently made that the achievements of the last fifteen years indicated an increment of at least five years to the average life-span of our people. Who then shall say that the study and practise of hygiene and sanitation—of preventive medicine—is of no practical value?

It will be well to note at this point the marked reflex influence that the adoption of an accurate or improved method for the registration of vital statistics has upon the sanitary status of any part of the population. Wherever a city or a State has adopted such a method there has almost immediately followed an improvement in its morbidity- and mortality-rates, for which reason the conditions obtaining in the component parts of the total "registration-area" of the United States are undoubtedly better than in similar or comparable portions of the remainder of the country. The registration-area is considered to be the combined areas or localities where, there is an "approximately complete registration of deaths

[1] It should be noted that the above rates are not strictly comparable, as the "registration area" has been materially changed and increased during the period in question. Thus, it represented 40.5 per cent. of the population and but 7.1 per cent. of the land area of the country in 1890, as against 85.3 per cent. of the population and 66.1 per cent. of the land area in 1922.

[2] Report on National Vitality, Its Waste and Conservation: Irving Fisher, 1909.

(at least 90 per cent. of all deaths) and where the data at hand show that the deaths were recorded properly under state laws, or, for cities, under municipal ordinances."

Nevertheless, there is still much to be done. Tuberculosis, which formerly was said to cause from one-seventh to one-fourth of all the deaths in the civilized world, is a preventable disease, and we now not only know its cause, but also have efficient means for cure in a large proportion

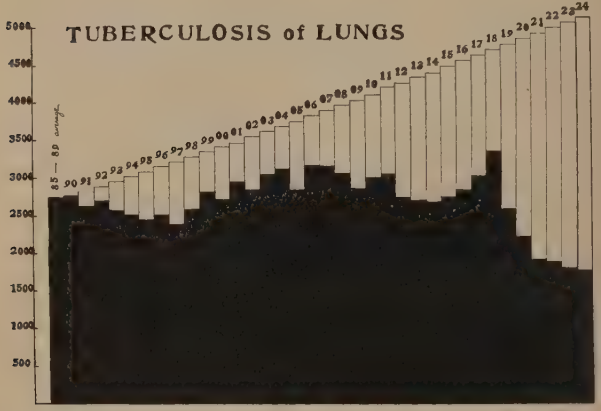


FIG. 3.—Showing the number of deaths from tuberculosis of the lungs in Philadelphia for each year since 1890, and indicating a total saving of over 41,000 lives by the lowered mortality-rate.

of cases, as well as for its general prevention. So with a number of the other infectious diseases. Almost every day marks an increase in our knowledge of their etiology and the securing of immunity from them; and not only must physicians make use of this knowledge as they acquire it, and employ their utmost endeavors to secure the enactment and enforcement of sanitary laws and regulations, but they must also realize that a large part of

their work lies in the enlightenment and education of the people in all matters pertaining to the public health.[1]

The plague that was the bane of Europe centuries ago and that has been a scourge to Asia since, occasionally threatens us at our western gates and is rife in some of our newly acquired colonial possessions. The infectivity of pneumonia is not appreciated by the laity nor by some physicians. The death-rate (102.1) in the Registration area in 1922 due to all forms of this disease was higher than that for all forms of tuberculosis (97) and was only exceeded by that for acute endocarditis and other organic diseases of the heart (165.7). We must not forget that pneumonia, which can be so pestilent, is "more or less limited to centers, corresponding in the main to the most densely populated area, with their allied conditions of squalor and poverty,"[2] and that it is our duty and for our own safety to improve the sanitary conditions and environments of such areas and centers. With our present knowledge of the value of vaccination, there have been far too many epidemics of smallpox within comparatively recent years. Carelessness in the application of protective measures has cost many lives and much money. There can be no safe cessation in prophylactic efforts. So, also, each and every one of the communicable maladies must be continually investigated and studied, and all positive information gained concerning them must in turn be imparted to the people who need protection against them. On the other hand, it is becoming more and more evident that any community may have good health, that is willing to pay

[1] It is encouraging to find that, although over 7.7 per cent. of the whole number of deaths recorded in Philadelphia in 1922 were caused by consumption, a progressive and marked lowering of the death-rate from this disease in that city is taking place, and that, notwithstanding an increase in population of 84 per cent., the fatalities from this disease are over a thousand less in number than they were over thirty years earlier. For example, the deaths from pulmonary tuberculosis in 1885 numbered 2821, and in 1886 were 2834, rates respectively of 297 and 292 per 100,000; while in 1922 there were only 1705 deaths, or a rate of 106.7 per 100,000 living.

[2] J. M. Anders, Journal of American Medical Association, May 9, 1903.

for it, and that low sick- and death-rates largely depend upon an efficient administration of the functions of public health service.

Order of Study.—In the preparation for a study like the one on which we are about to enter there is some question as to just what may be the most advantageous order and arrangement of the subjects to be treated. For instance, it would be interesting to discuss our science in its relation, in turn, to the individual, the household, and the people in general—that is, Personal, Domestic, and Public Hygiene; and to show wherein the treatment of these subdivisions is similar and wherein they differ. Such a threefold consideration would be not only logical, but extremely instructive as well.

However, since there are certain fundamental considerations and conditions common to all these subdivisions, and since the bacteria and other microörganisms have been shown to have so important a part in many of the processes intimately connected with health and disease, it will doubtless be advisable to devote the next two or three chapters to a brief review of these factors as they affect the causation and transmission of disease and the preservation of health. This done, it seems to the writer that we shall, as beginners obtain a more comprehensive and thorough view of our subject if we pursue a method somewhat as follows: First, to discuss air, water, and food—three things essential to life—in the varying conditions and circumstances under which they may affect the physical welfare, either for good or bad, of the individual or of the community. Then to take up, in such order as may seem best, the other themes, such as climatology, habitations, disinfection and quarantine, disposal of sewage, clothing, exercise, school hygiene, etc., whose consideration, on account of their influence in the preservation of health and prevention of disease, is only a degree less important than those already mentioned. In this way, while the whole ground may not be covered, the importance of the various subdivisions may be estimated in their relationship to one another, and we

shall be the better prepared to pursue the study as later opportunity may offer.

It is doubtless in place just here to review briefly the reasons why it is important that every intelligent person who desires to foster his own welfare as well as be a good citizen should know something of this great subject. Every one appreciates that it is the special duty of the physician to be able to recognize and correct insanitary conditions wherever they may be found, and why he should make particular and constant study of the science in all its branches and developments, but few of the laity realize their own opportunities or obligations in this respect.

Every true physician soon finds that the respect and affection of his patients and associates are worth far more than mere mercenary gain, and that his highest aim should be to prevent disease rather than simply to cure it; and, though this may seem to militate against his personal interests, he is unworthy the name of physician if his object and purpose be solely or primarily to make money. However, the observer quickly learns that in a community kept in good health and sanitary condition there will always be more or less need of a doctor's services in spite of every effort to prevent sickness, and that such a community will pay more promptly and more liberally for such services than one in which sanitary precautions are neglected. Health means ability to work and to earn good wages; and a healthy community means more business, more money, and more comforts.

If, now, the physician's patients, or at least those of them who are intelligent, understand the facts and principles underlying the causation of disease, the methods of transmission and the practical means of preventing and eradicating the infectious maladies, not to speak of the broader and more important knowledge that serves for the maintenance of good health in general, the work of the physician in conserving the public health as well as that of individuals will be sustained and made the more

effective to the ensuing benefit of the community. We may note here the close relations existing between sanitary science and social and political economy—a relationship which is very intimate, as we shall see from time to time in our work, for as the physical condition of a people is bettered, it becomes more possible and more certain that they will likewise improve both mentally and morally.

Again, though the science of hygiene and sanitation is comparatively a new one, public attention is being strongly directed toward it, not only because it vitally interests every one, but because new discoveries and new applications of the laws pertaining to it are being constantly made, which are, in turn, swiftly given to the world by both the scientific and the popular press. This creates a demand for first-class investigators, teachers and workers, which demand is bound to increase in the near future and promises materially to exceed the supply. In fact, within recent years not only the medical but also some of the academic and scientific schools of the country have already made Hygiene a feature of their regular courses, and others will soon be compelled by public opinion to establish in their faculties well-equipped and liberally endowed chairs for instruction in this important science. It will not be long before the people in general realize that it is fully as important that the college student or graduate be instructed how to do his part in taking care of the health of himself, his future family and the community in which he is to reside, as that he shall be well taught in the abstract principles of science or the classics of dead languages.

So, also, considerably more time and attention than are now accorded to it should be given to hygiene in the work of the various normal schools for teachers. The graduates of these schools will have much of the physical as well as the mental welfare of thousands of young and growing children in their keeping, and it is unquestionably their duty to prevent or obviate the ills of school-life as far as lies in their power, and to inculcate and give instruc-

tion in habits of living which will continually tend to preserve and improve the physical health of those under their care. The large proportion of young men in this country recently rejected as being unfit for military service because of physical deficiencies has awakened public interest to the importance of this subject as never before and methods and means are being sought whereby the tremendous loss in economic efficiency due to this cause may be prevented.

There is also need for trained sanitarians in the service of the various states and the large municipalities, and there is now an actual demand for such men and women with no corresponding supply in view.

As a matter of course, a modern physician must necessarily have a knowledge of hygiene, preventive medicine, and sanitary science. Many states require as thorough examinations in this as in any other branch of medicine before granting the right to practise within their boundaries. Even more so do the Army Medical, the Navy Medical and the Public Health Services of the Government, lay stress on this branch and the constant demand for an increased personnel in each of these as well as the experience gained by all three during the late world war, must emphasize the value and necessity of a thorough knowledge of hygiene, sanitation and preventive medicine on the part of those who may anticipate enrollment in any one of these branches of the public service.

Moreover, the people generally, as has been intimated, are awakening to an interest in sanitary matters and the prevention of disease, and expect their physicians to be well versed on all pertaining subjects; if they find one lacking in knowledge or interest in this respect, they are apt to think, rightly or wrongly, that he will also be deficient in the other branches of medicine.

They will always look to him as their instructor and adviser in matters pertaining to health and physical welfare, and he cannot afford to be found lacking in this any more than in any other part of his professional work.

But there is almost as much reason for a similar knowledge of the principles of hygiene being made a part of the intellectual equipment of every intelligent man or woman. One's physical welfare depends largely upon his appreciation of the health hazards to which he may be exposed and the care taken to guard against or avoid them. Hygiene has to do with practically every function of life, and sanitation is an important factor not only in the conduct of the home but of one's business. The hygiene of occupations and industry is already a very large field in itself and demands the attention of every employer of labor and business head, while commercial enterprises in many lines must always be more or less dependent upon sanitation as regards places, methods and things. Thus, there can scarcely be a general subject of study of so much importance as this for any one who has a sincere interest in the welfare of himself as well as others, and it, therefore, should no longer be considered as one mainly within the province of physicians and special teachers of the science.

It is evident that the successful physician and the practical student of hygiene must have a thorough knowledge of at least two things: (1) Health and its laws; how to obtain and preserve it. This of course, implies some knowledge of the human body and its functions, viz., of anatomy, physiology, and physiologic chemistry. (2) Disease and its causes and nature. They must also understand the distinction between diseases due to causes external and those due to causes internal to the body; and that while some of these causes may be prevented or modified, others, with our present knowledge, may not be so readily overcome. (3) In addition to these the physician must also know his therapeutic agents, both preventive and curative. He must be conversant with and know how to use those which he has at his disposal, including not only drugs, but also all substances and forces that he can make efficacious to his purpose. The workman must know his tools to be able to use them intelligently.

Health is "that condition of the body and its organs necessary to the proper performance of their normal functions;" and disease may be defined as "a condition of the body marked by inharmonious action of one or more of the various tissues or organs, owing to abnormal condition or structural change."

Just here it may be well to say that, as ordinarily used, health is a relative term. Many believe that they are in good health simply because they are not ill and can attend to the ordinary duties of life and business in a fairly satisfactory manner. As Williams[1] says: "There is in this definition of health, as freedom from disease, no appreciation of the varying degrees of healthfulness among those usually classed as well, and no understanding of the heights that could be attained in human health and living if all the available means for improving health were employed. One need be only a casual observer to recognize that a great number of people are living below their best level of attainment. Many persons believe themselves healthy because they are not sick in bed, and this lack of appreciation of health as a quality of life prevents the realization of a greatly superior type of life. It is, perhaps, impossible to say how far any individual could progress in achieving a finer and higher level of living. It is not too much to say, however, that health, as an idea, should imply more than freedom from disease. Such broadening of the idea would bring not only increased health values but also desirable social values.

"It is of value to think of health as that condition that makes possible the highest enjoyment of life, the greatest constructive work, and that shows itself in the best service to the world. It involves keeping the body and mind at the highest levels, living at one's best and not being satisfied with mere absence from the hospital and sick room. This concept of health, moreover, parts company with that idea of health that takes it as an end of life.

[1] Williams, J. F.: Personal Hygiene Applied, 2d ed., pp. 17, 18, 20.

It refuses to consider as healthy the individual who employs a wonderful physical body for purely selfish and socially undesirable ends.

"Health may be defined, therefore, as *the quality of life that renders the individual fit to live most and to serve best. Health as freedom from disease is a standard of mediocrity; health as a quality of life is a standard of inspiration and achievement.*"

Disease is a pathological or abnormal physiological state, not a spiritual thing; a condition, not a theory. Consequently it is to be fought and, if possible, conquered with matter, natural forces, and physical means, though not necessarily with violence. In fact, when once we understand the minuteness and delicate structure of the ultimate cells and tissues affected, we realize that oftentimes the gentlest application of the forces and means employed may be the most helpful and efficient. But when one has seen the ravages caused by disease, as revealed in the pathological laboratory and at autopsies, not to speak of its manifestations in the living as seen in the sick-room and in hospitals, I am sure that he cannot logically, even for a moment, give credence to those who proclaim that it can be dissipated by the mere action of mind or of faith or by any other than rational and scientific measures. Virchow gave a priceless boon to modern medicine in his theory of cellular pathology and in showing its superiority to the old humoral theories and *a priori* reasoning. He wrote "whatever outside of a cell acts upon it (abnormally), works a mechanical or chemical change within it, which change is disorder or disease." The sooner we realize that the laws of physics and chemistry govern cell life and action and, consequently, the functions and organs of the body, the more accurate will be the treatment and the more certain the prevention of disease.

For convenience sake, diseases may be divided into two main classes, somewhat different in their origin, nature, and character, although the line between the two is not

always clearly marked. Diseases of the first class arise *within* the body, and may be called *autogenetic*. They are usually due to some alteration or disturbance of nutrition and assimilation, such as irregular absorption of products of digestion; or of function, such as that of elimination, to either of which, as well as to other similar causes, various auto-intoxications may be due. The second class comprises those which are due to causes from *without*, favored, it may be, by either internal or external predisposing conditions, but each malady of necessity depending upon the reception or inoculation of the special cause, which cause has the power of reproduction and development, of vitality and virulence. Such diseases are called *contagious, infectious, specific, inoculable,* or *zymotic*.[1]

In the first class, with our present knowledge, we may place such maladies as gout, diabetes, neurasthenia, etc.; while into the second will obviously fall all that are now known to be due to living "germs" or organisms, such as cholera, typhoid fever, malaria, etc. However, we must not overlook the impulses often given to the causation of certain members of the second class by faulty conditions of nutrition or assimilation, as is especially exemplified in many cases of tuberculosis. The character of the soil may influence the growth and product of a plant almost as much as the species itself, and so the difference in constitution and tissue of individuals may materially determine the variations in symptoms and virulence so often manifested by an infectious malady.

[1] In this connection the following quotation from Sedgwick is interesting: "Diseases may be regarded as due either to defects in the constitution or construction of the vital mechanism, or else to external unfavorable influences acting upon it. From the point of view of origin or causation, all diseases may be divided into two classes, viz.: (I) *Constitutional*, or (II) *Environmental*. This classification, while open to many objections, is of the highest value to the physiologist and the sanitarian, for it brings the former face to face with intrinsic, structural, or organic defects in the mechanism, while the attention of the latter is concentrated upon those abnormal external influences which act unfavorably upon the organism, and which he must seek, and may be able to remove." Principles of Sanitary Science and Public Health, 1902, p. 10.

A third class or a subdivision of diseases might also be indicated, which would include those disturbances which are almost purely psychical and whose symptoms are largely notional and the result of perverted emotion, imagination or coördination. But it is a question whether the primary cause of almost all such disorders is not an altered and abnormal nutrition or functioning of the general nervous economy of the body, or the symptoms simply reflex manifestations of irritative disturbances of distant organs.

Prophylaxis is "the use of hygienic or other precautions conducive to the prevention of disease;" or it may be defined as "a series of methods or procedures whereby disease is restricted and prevented by suppressing or removing its predisposing conditions, and destroying or modifying the exciting causes." Its first function of suppressing or removing predisposing conditions is accomplished by *hygiene* when these conditions pertain to the body structure itself, and by *sanitation* when they are more nearly related to the surroundings or "environment" of the body; the second, that of destroying or modifying exciting causes, is carried out by *disinfection*, using the term in its broadest sense. The term "predisposing conditions" should be used instead of "predisposing causes," because these conditions, cannot in themselves originate a disease, though they may and often do make the system more susceptible to the exciting causes of a disease. For example, the predisposing factors of tuberculosis—"privation, depression, and excess"—are conditions, and though they often prepare the tissues for the development of the malady, it can only occur after infection by the exciting cause, viz., the specific tubercle bacillus.

As we have, as yet, little definite knowledge of the exact nature of more than a few of the exciting causes of autogenetic diseases, they being developed and elaborated within the body, and as disinfection, or the destruction and modification of exciting causes, is an important feature of prophylaxis, we at present naturally look for more

immediate and satisfactory results in the application of prophylaxis to the second class of diseases; but this does not prevent or restrict the employment of certain prophylactic measures in regard to the first class, such as the selection of proper diet, clothing, climate, etc., and the removal or counteracting of all influences favoring malnutrition or imperfect and improper functional activity. We may therefore say that hygiene and sanitation are the defensive, disinfection the aggressive part of prophylaxis.

Nor does this doctrine contravene the teaching of the "new" hygiene that the body must develop a specific resistance for each specific poison or other harmful influence to which it may be exposed, and that disaster will result if such exposure be too sudden or severe before the necessary specific resistance be developed. For, while this is doubtless true, common sense will indicate that any particular resistance will be more speedily and better developed by healthy cells and tissues in full vigor at the time of exposure or attack than by weak and sickly ones. Therefore, without minimizing the importance of securing such special protection by every practicable means, it will nevertheless be the part of wisdom to endeavor to foster and secure general good health by every means possible.

To suppress and remove predisposing conditions and to prepare the body to resist and repel the action of exciting causes, we must not only strengthen its powers of resistance, but also make all external media as favorable to health and as hostile to the exciting causes as possible. The defensive powers of the body must lie in the individual cells and tissues of the body, including the vital fluids, and it is but reasonable to suppose that this repellent action to noxious substances is best performed when the cells and tissues are in most perfect health and most vigorous condition. This is not only good logic, but all experience and scientific research go to show that it has a firm foundation in fact.

We shall soon learn that purity of the external media

and environment of the body is essential to its welfare and that of its component tissues, and that conditions of impurity in these media predispose to disease. We shall also learn that a proper and sufficient supply of wholesome food is essential to health, and that certain other factors, as sex, age, clothing, climate, etc., may act for good or ill in the determination of the balance between health and disease. In other words, if we strengthen the resistant powers of the system to the fullest extent and remove all predisposing conditions, in all probability the exciting causes will be inoperative in most cases, and there will be no incurrence of disease. This is the essence of the *art* of hygiene and sanitation: to secure perfect health, to increase the inherent power to resist noxious and harmful influences, and to make all the surroundings and environments of the body safe and free from depressant factors. This applies equally to both classes of disease; for with healthy cells and proper food there will not be faulty nutrition and assimilation or improper functioning and the consequent production of the exciting causes of autogenetic disease; and with a vigorous resistance and wholesome environment there is less opportunity for the germs of infectious maladies to obtain a foothold within the system long enough to reproduce themselves and cause their characteristic disorders. The best means, therefore, of preventing disease is to learn and apply the best methods of attaining and retaining a healthy and vigorous state of the system, viz., to determine and observe the laws of hygiene and sanitation.

CHAPTER II.

BACTERIOLOGY AND PARASITOLOGY.

The increase in the knowledge concerning the lowest forms of life, and the discovery that these often have a causative action in the excitation of many maladies, have greatly facilitated the study of the prevention of disease. In fact, it is largely to this advance in knowledge and to the confirmation of the germ theory that much of the success of modern hygiene and sanitation is due. In addition many species of bacteria and other microörganisms are of extreme importance because their function is that of scavengers, continually working to remove and convert the useless and harmful wastes of the world into material of high value as food for organic life; while still other kinds are being found to have great value in many economic and commercial processes. A review of the chief facts concerning them will therefore be in place at this time.

The unicellular vegetal microörganisms divide themselves into two general classes with respect to their manner of reproduction, viz., those that multiply by budding —the *blastomycetes*—and those that increase by simple division or fission—the *schizomycetes*. In the first class we have the hyphomycetes or mould-fungi, and the saccharomycetes or yeasts, examples of these being familiar to everyone. However, it is with the fission-fungi, or *bacteria* as they are now more generally known, that we are most concerned as sanitarians, since they practically include almost all those vegetal microörganisms that are more or less closely connected with the production of disease as well as with the removal of offensive matter. Comparatively few of the yeasts and moulds are pathogenic, and then only indirectly or in a minor degree.

Bacteriology, then, is the science of those unicellular vegetal microörganisms that multiply by direct transverse division (fission), or, as occasionally happens, by the development of spores. Its study consists in the examination by means of the microscope of the form and method of growth of these minute plants, in their artificial cultivation on or in suitable media, and in the determination of the effects of the inoculation of pure cultures upon animals. To these may be added another field of research that gives promise of much development in the near future, viz., the study of the chemistry of the bacterial products and of the reactions produced by their presence in culture-media and in living tissues.

Although more than two centuries have elapsed since the discovery of the bacteria by Leeuwenhoek (about 1680), and though Plenciz advanced as early as 1762 what is practically the germ theory of today, most of our knowledge concerning the physiology, methods of cultivation, and differentiation of the bacteria has been acquired within less than half a century. It is true that some earlier advance had been made in sterilization, and that Cohn, by establishing the fact of spore-formation, demolished the last arguments in favor of spontaneous generation and confirmed the science of bacteriology; but until the last four decades we had but little knowledge as to the means of separating and isolating the different species and making pure cultures, or of preparing culture-media, staining, etc.

As has been intimated, the bacteria are unicellular organisms, usually multiplying by a process of cell-elongation and fission. Being without chlorophyll, they cannot absorb and decompose carbon dioxide and ammonia, as do the higher plants; but require for their growth and nutrition organic matter—usually soluble albumin—in the presence of moisture.[1] Hence, they must be either saprophytes

[1] It will be understood that these statements and many of those to follow are more or less general, and that certain species of the bacteria may present notable exceptions.

or parasites. As the combination of albuminous organic matter and water is extremely common, so the distribution of the bacteria over the earth is wide-spread and practically universal.

Some of the bacteria may, under adverse conditions, such as lack of nutriment or of moisture, too alkaline or too acid a medium, extremes of temperature, etc., or on the other hand, as a result of the attainment of a stage of maximum development, produce spores which are much more strongly resistant to deleterious influences than the

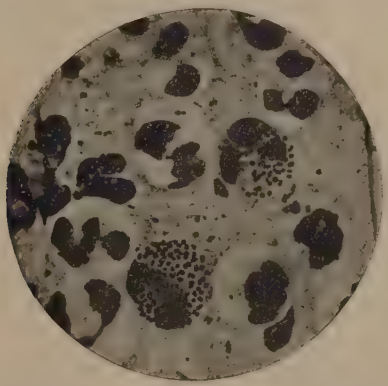


FIG. 4.—Micrococci (gonococci) in pus-cells. × 1000.

bacteria themselves. In this way the spore-forming species may often survive the action of disinfectants or other agencies that are sufficient to destroy other bacteria. Upon the resumption or recurrence of favorable conditions the spores develop into cells similar in form and nature to their parent cells. It is to be remembered that spores do not reproduce spores, and that "a single cell produces but one spore."[1]

[1] Abbott, Principles of Bacteriology, 1st ed., p. 31.

Under the microscope the spores are seen as highly refractive, spherical bodies that stain with difficulty, and evidently have a very resistant envelope, probably of cellulose. The interior of bacteria and spores is protoplasm. So far as is positively known at this time, only certain of the bacilli form spores, while a few of the spirilla and one or two species of micrococci probably have the same faculty.

Again, under certain peculiar conditions some organisms may develop another morphological change, the so-called

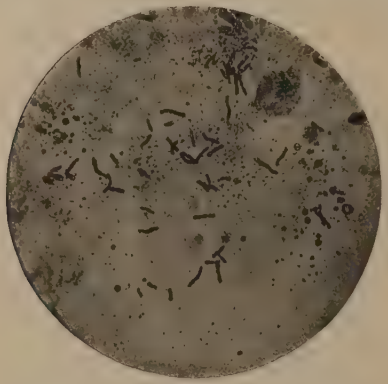


FIG. 5.—Tubercle bacilli in sputum. × 1000.

involution-forms. These are doubtless pathologically distorted cells, with probably diminished resisting powers, but which will revert to the normal type under favorable conditions, providing the unfavorable environment does not kill them.

Lastly, at times certain individuals of a species seem to have departed from the typical form, but these departures are only different phases in the normal development. Thus a young bacillus may be shorter than the adult and look much like a coccus, or a coccus about to undergo division

may be oval in shape and considerably larger than the quiescent members of its species. But one form of bacteria never permanently takes that of another—micrococci are always micrococci, bacilli always bacilli, etc.

It is not within the province of this book nor does space permit to give a thoroughly scientific classification of the bacteria, even were it desirable to do so. However, there are a number of ways in which we may subdivide them, none of them exactly scientific, perhaps, but still sufficiently accurate and convenient for our purpose. If we consider the bacteria as to form, we have: (*a*) *micrococci,* spherical in shape; (*b*) *bacilli,* which have one diameter longer than another; and (*c*) *spirilla,* spirals or segment of spirals.[1] We shall have more to say hereafter of the characteristics of each of these subdivisions. Accordingly as they live best with or without air or oxygen they are *aërobic* or *anaërobic.* Again, they may be named according to their product—*e. g.,* some produce colors, *chromogenic;* others pus, *pyogenic,* etc. Lastly, they exist and grow either as *saprophytes* upon dead, or as *parasites* upon living organic matter. We also say that an organism is *optional* or *facultative* when it is at one time a saprophyte and at another a parasite, or at one time aërobic and again anaërobic; and that it is *obligate* when it has not this property of changing its nature according to surrounding conditions.

Some of the micrococci are named according to the manner in which they grow. If in pairs, they are called *diplococci;* in fours, *tetracocci;* in threads, *streptococci,* etc. Groups or masses of micrococci or bacilli held together by a gelatinous substance are called *zoöglea.* As compared with other bacteria, with some few exceptions, we know but little about the spirilla. The germ of

[1] Accurately speaking, some of the so-called higher bacteria have more elaborate development and distinction as to form, but as our present discussion has almost entirely to do with the phenomena of the lower and simpler bacteria, the former may henceforth be omitted from the discussion.

cholera—the comma bacillus (?)—belongs to this class, and the cause of relapsing fever is also probably a spirillum.

Most of the bacteria thrive best in culture-media that are neutral or only slightly alkaline, though a few species seem to do better in slightly acid surroundings. So, also, they do best at temperatures ranging between 20° and 40° C. (68° and 104° F.), though they may grow at any temperature between 5° and 43° C. (41° and 109.4° F.). Any marked deviation in the culture-media from the neutral point or continued exposure to extremes of tem-

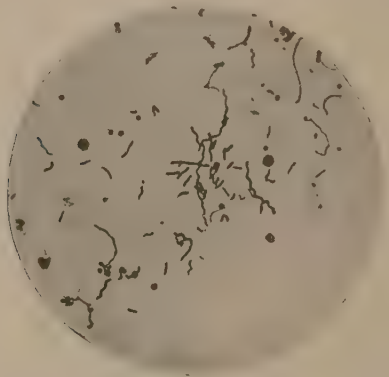


FIG. 6.—Spirillum of Asiatic cholera. × 1000.

perature may either check the growth of the organisms altogether, and eventually destroy them, or may cause spore-formation, or the production of involution-forms, or a change in the composition and the character of the chemical products which the bacteria normally produce. This also holds good with respect to any other condition or substance that may be deleterious to the bacteria in their normal state; wherefore we shall see that such factors are important as having a decided influence in altering the virulence of pathogenic bacteria and in suggesting methods

for bringing about a condition of immunity to their attacks.

As it is rare to find isolated individual species anywhere except in pure cultures artificially prepared, it is evident that we must devise some way of separating the different kinds of organisms one from another. This is best accomplished by the method suggested by Koch, viz., to introduce the mixed kinds into some melted culture-medium, like nutrient gelatin, which solidifies on cooling, but whose melting-point is not sufficiently high to destroy

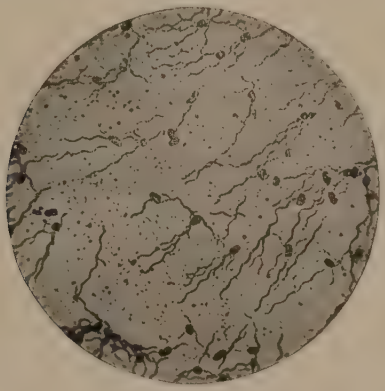


FIG. 7.—Bacilli of hog cholera, showing flagella. × 1000.

the vitality of the germs. If the fluid be well shaken, the various species will be distributed through it, and, upon cooling, each individual or group (zoöglea) of individuals of the same kind will be fixed in its place and become the starting-point of a *colony* of that special kind. Moreover, if the gelatin before cooling be poured upon sterilized glass plates or into flat (Petri) dishes (Fig. 8), the subsequent work of counting, examining, and making cultures from the colonies thus secured will be greatly facilitated, while by transplanting and repeating the process one or

more times, absolutely pure cultures of each species in the original mixture may be obtained.

Special care must be taken in this, as in all other bacteriological methods or operations, to prevent contamination of cultures, media, or apparatus by other organisms which are almost omnipresent, and which would prevent accurate results or deductions were they not rigidly excluded or destroyed. Obviously, we may not use chemical disinfectants or antiseptics as a means of destroying the interfering microbes, for such procedure would kill or inhibit the growth of the bacteria we desire to cultivate; but we must sterilize by heat all the articles used, together with their contents. This, if properly done, does not affect the nutrient properties of the culture-media, while it does remove the danger of contamination already present.

FIG. 8.—Petri double dish (now generally used instead of plates).

In sterilizing we may use either dry or moist heat, the latter being far more preferable in most cases, since to be effectual it does not require so high a temperature nor so long a time as does the former. Moist heat, especially in the form of steam, is more penetrating than dry heat; beside, dry heat must be of so high a temperature that it may render useless for culture purposes such substances as nutrient gelatin. Glassware and the like, however, may be quickly and advantageously sterilized by dry heat. On the other hand, certain substances, like blood-serum, are spoiled for culture purposes even by moist heat continued sufficiently long to kill the spores possibly present, as the latter require a higher temperature or more prolonged heating to sterilize them than the bacteria without spores. Resort is therefore had to *fractional sterilization*

in such cases, exposing the materials for only a short time to a temperature just sufficient to destroy the bacteria, repeating the process after an interval, say twenty-four hours, which is presumably sufficient to allow the spores to develop into bacteria; and again a third time, after a like interval, to insure absolute sterilization. Previous to sterilizing the culture-media and apparatus, the test-tubes, flasks and similar vessels are

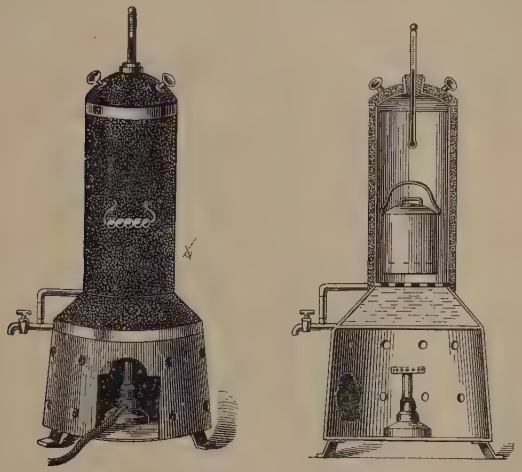


FIG. 9.—Steam sterilizer, pattern of Koch.

stoppered with plugs of cotton-wool in order to prevent the subsequent access of contaminating organisms, and these are afterward covered, when necessary, with rubber caps or paraffin wax to prevent the evaporation of the culture-fluids, or of moisture from the gelatin, etc.

As a basis for a number of culture-media we may use beef-broth or bouillon, which is a fluid especially favorable to bacterial growth in that it contains an abundance

of albumin in solution. When a solid medium is desired, either gelatin or agar-agar (a gelatin-like substance obtained from Japan) may be added to bouillon, giving nutrient gelatin and nutrient agar-agar. Of these, the gelatin has a melting-point below the temperature of the human body, while that of agar is above; consequently we employ the latter when it is desired to cultivate germs that grow best at the body temperature, although the development of most bacteria is usually more rapid and

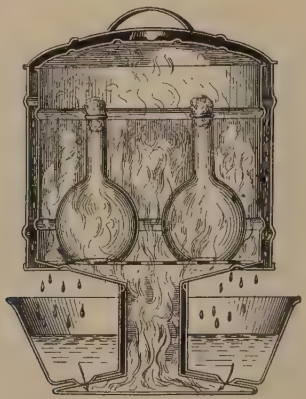


FIG. 10.—Arnold steam sterilizer.

characteristic upon gelatin. Blood-serum, sterilized and solidified, is also used for the cultivation of certain organisms, such as the diphtheria bacillus; and there are certain others which can best be identified by their difference in growth upon boiled potato, milk, etc.

The differentiation of the various species of bacteria is to be made by noting their appearance and form under the microscope, whether they are motile or not, how they take different stains, etc.; by observing their methods of growth in or upon different culture-media, and the color

and appearance of the colonies, as well as variations in color, reaction, etc., in the culture-media; by noting whether they are aërobic or anaërobic, or facultative, and at what temperatures they thrive best, etc.; and finally by studying their action and the effect of their products upon living animals. In this way we may determine the characteristics of each individual or species, and will eventually have the data for a strictly scientific classification of the bacteria in general. For example, the organisms causing suppuration are usually micrococci, occurring in clusters (staphylococci) or in chains (streptococci); the cause of typhoid fever is a bacillus, and the cholera germ belongs to the spirilla. The tubercle bacillus stains with marked difficulty, but when stained is not readily decolorized by

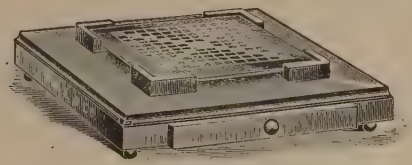


FIG. 11.—Ruled square for counting colonies.

a weak solution of nitric acid, as are most other bacilli. Some bacteria liquefy nutrient gelatin, others do not, and almost none liquefy agar-agar. This liquefaction is not a melting, but rather a kind of peptonization, since the gelatin will not solidify after this occurs, as it does after being subjected to moderate warming. Again, some bacteria produce one particular color or chemical substance in the presence of oxygen, and another in its absence; some produce color only in the light, others only in the dark, etc. Finally, different pathogenic microbes cause different maladies when inoculated in animals or human beings, and the same germ may produce different results in animals of different species or families.[1]

[1] See Kenwood's Hygienic Laboratory, pp. 466–470; also McFarland's Pathogenic Bacteria, pp. 46–57.

The subdivision of the bacteria into saprophytes and parasites has already been noted. Therefore it must be remembered that not all of these microscopic plants are disease-producers; much the larger proportion, in fact, being benefactors rather than otherwise to the human race.

FIG. 12.—Pocket-case containing sterilized culture-tubes, platinum needle, and alcohol lamp, used for obtaining cultures for diagnosis, etc.

The function of many of the saprophytic organisms is to change dead organic matter into simpler chemical compounds and ultimately into end-products such as carbon dioxide, ammonia, and water, these latter substances being once more utilized in the nutrition of the higher forms of vegetable life, which are in turn necessary to the existence of the animal life upon the globe. One should also understand that some of the saprophytes in the soil seem to possess a constructive or synthetic power,

elaborating more complex plant-foods from the simple compounds mentioned. Indeed, it is only when the student of hygiene fairly realizes the wide scope of the functions of these minute but almost omnipresent scavengers that he will comprehend the important part they play in the purification of our environment. In the air they possibly help the oxygen to destroy the harmful effluvia and exhalations of men and animals and the floating débris of organic substances; in the soil, the common receptacle of the wastes and refuse of vital activity, they quickly and continually convert these noxious additions into foods of the highest value to growing plants; in running streams and quiet pools they are of the greatest importance in the removal of the dangerous impurities washed from the surface of the land or recklessly discharged from human habitations, factories, and the like. And not only do the saprophytes help mankind in this way, but members of the class are beneficent in many others. For example, they enable those plants, the leguminosæ, which yield us the largest supply of vegetable proteids, to derive much of their nitrogen almost directly from the atmosphere; they have much to do with the flavor and value of dairy products, and uses in which they may be employed in the domestic and commercial affairs of life are being newly announced from day to day. Thus we find the bacteria of this class, which comprises by far the greater number of known species, to be our benefactors and indispensable servants both in preventing the accumulation of noxious and harmful substances upon the earth, and in helping to produce the food which we eat and many other things that we need and use in our daily life.

The parasitic bacteria, on the other hand, have their habitat in or upon highly organized living matter, and exist at its expense. They may also produce in their growth poisonous substances, called *toxins* and *toxalbumins*, that are either locally or generally harmful to the organism that is their host. It is needless to say that it is in this

class that we find the disease germs, or *pathogens* as some would call them. It should not be forgotten, however, that the saprophytes, in bringing about the decomposition of complex organic bodies, may also produce *ptomaïns*, which may or may not be toxic to animal life. Of these latter, we may instance as good examples the cadaveric poison of the dissecting-room or the dangerous tyrotoxicon, a by no means uncommon product in the decomposition of milk or ice-cream. But though ptomaïns may be more or less characteristic of the respective bacteria that produce them, each varies in its composition and properties according to the substance upon or in which it is produced, while the toxins are specific derivatives or "active principles" of their respective microörganisms. In other words, different kinds of saprophytes may produce the same ptomaïn from a given organic substance, but each toxin is the product of its own particular species of bacteria and is independent of the latter's place of growth or environment.

Considering for the present the pathogenic bacteria alone, we are naturally brought to the discussion of the *germ theory*, which is, that the exciting cause of each contagious or infectious disease is some specific parasitic organism, and that each of these diseases is only communicated by the transference and development of its particular parasite or germ within or upon the tissues of the infected individual. Consequently such diseases are transmitted from one person to another, or in some cases from animals to men or *vice versa*, by means of these microorganisms, and the transference is by air, water, food or other fomites, by insects or by direct contact. It is evident that if acquired knowledge establishes the truth of this theory, the prevention of infectious diseases is greatly simplified and becomes merely a matter of combining effective sanitation, of which we have spoken, with the destruction of the specific exciting causes *i. e.*, disinfection. Nor is it essential that we any longer make the distinction between the terms "contagious," "infec-

tious," "zymotic," and "specific," that formerly obtained, since they may practically be used synonymously. The first of these terms used to be applied to those diseases which were believed to be transmitted most frequently by direct contact, and *infectious* to those of which the transmission is usually by fomites. But we know that germs of the former class may be transmitted by air, water, food, etc., and those of the latter by personal contact, though the reverse is what usually happens in the respective cases. Occasionally disease occurs also by *inoculation*, the exciting organisms being introduced into the body either accidentally or intentionally through some wound in the protecting skin or mucous membrane. The term *zymotic* was formerly applied to those diseases occurring in epidemics, and which were supposed to be due to fermentative processes: if used at all, it should be given to any disease due to a living germ. The term *specific* should only be given to those maladies which have a specific origin—*i. e.*, which have been proved to be due to a single and particular organism.

In this connection we may define an *epidemic* as "an outbreak of a communicable or infectious disease affecting a dozen or more individuals in quick succession before the recovery of the first case, whether arising from a single focus or several foci in a neighborhood."[1] An *endemic* disease is one occurring more or less constantly in a certain locality. When an epidemic extends over a very large territory, it is said to be *pandemic*.

That all communicable diseases are due to vegetal germs or kindred animal organisms is more than probable, and while there are some for which this has not been fully proved, it is scarcely possible that any of these may arise from insanitary conditions alone without the presence of a living causative organism.

The reasons for believing in the germ theory are based on established and logical facts as well as theoretical

[1] Committee of American Public Health Association, 1898.

hypotheses. Even if we ignore the scientific research work already done, it is evident that that which causes a disease —the *contagium*—must, when introduced into a susceptible person or animal, increase in quantity to an enormous extent. Note, for instance, the large quantity of actively virulent matter thrown off from a case of smallpox or scarlet fever, and yet how very little is required to initiate an attack of the disease. No lifeless chemical substance has the power of being increased to such an extent by simply finding lodgment in a suitable medium. The causative factor or contagium, whatever it may be, evidently must have life and the power of reproduction.

Moreover, these causes of disease, when freed from the body, may be carried long distances, and may retain possibly for months or years their power for harm, only waiting a suitable field in which to multiply and cause the same malady as before. Such causes must therefore be capable of entering a state in which vitality is latent, and in which the reproductive functions are for a time inactive. But it is known that the spores of many bacteria, and sometimes the bacteria themselves, may be carried afar, kept for long periods of time, and even exposed to wide extremes of temperature, without being killed or losing their power of reproduction and rapid multiplication. Again, we know that substances that are poisonous to, or that prevent the development of, these bacteria and kindred low forms of life, do, when properly used, prevent or remove the danger of contagion and infection.

There is also in the development and progress of infectious disease a direct analogy to the phenomena of fermentation, whose causative organisms are of the same order as these which we are considering; the same rapid multiplication of cells in suitable media at proper temperatures—a period of incubation—and then changes in the infected body or host, which, after going on to a certain extent, check the further development and multiplication of the organism. What it is in the containing medium that checks the growth of the germ

we may not be able to determine *a priori*, but we may assume it to be something hostile to the contagium, as alcohol above a certain percentage in the fermenting medium is deterrent to the further growth of the yeast-cell.

Lastly, if the proof of Koch's postulates is essential to the acceptance of a given microörganism as the cause of a given disease, we must believe, on the other hand, that a certain germ is *a* cause, if not the only one, of a certain malady if these postulates be proven with respect to the germ and malady.

To determine whether an organism is or is not pathogenic it is necessary to experiment on living animals. To do this we must use pure cultures of the organism and carry out all our processes, including inoculations and autopsies, under strictly antiseptic precautions. For example, we may examine microscopically the blood and various tissues of a diseased animal; if bacteria be present in any of these, we make cultures from them, and if more than one kind of bacteria be present, the various kinds must be isolated and pure cultures made from each kind. When a pure culture is at last obtained, it may be studied both microscopically and as to its characteristics in various media and at different temperatures. Finally, healthy animals known to be susceptible to the disease in question are inoculated from the pure culture and, after the period of incubation, carefully watched for symptoms of the disease. Should these manifest themselves, the animal is killed and its blood and tissues carefully examined for the inoculated organisms. A similar study is to be made of each species isolated from the first animal.

The *postulates of Koch*, which are necessary to prove that a germ is the cause of a given disease, are: (1) The microörganism must be found in the blood, lymph, or tissues of a person or animal sick or dead of the disease. (2) The microörganism must be isolated from the blood, lymph, or tissues, and cultivated in suitable media outside of the animal body. These cultivations must be

carried on through several generations until a pure culture of the germ is obtained. (3) A pure culture thus obtained must, when introduced into a healthy and susceptible animal, produce the disease in question. (4) In the inoculated animal the same organism must again be found.

In the case of many diseases peculiar to human beings alone the third condition must remain undetermined and our chain of proof be broken, because we should not endanger human health or life by experimental inoculations. But in diseases common to man and animals the experiments necessary can be completely carried out, and where a germ can be proved to be the cause, according to these postulates, of the malady in animals, we can also fairly conclude that it is the cause of the same disease in human beings. The specific germs of a number of maladies common to man and beast have thus been determined, together with those of a large number of affections peculiar to animals alone.

Granting that a certain organism be pathogenic, infection by it will depend not only upon the susceptibility of the animal or person concerned, but also upon the method of entrance into the body, the number of microbes introduced and present, and especially upon their degree of virulence. Thus, the tubercle bacilli produce effects of different character and gravity in different tissues, and it needs no argument to show that while the normal resistance of the body may be all-sufficient to overcome a few vicious germs taken in with the air, food, or drink, it may be entirely inadequate to resist and may quickly succumb to large numbers of the same enemy, especially if the virulence of the latter be enhanced, as we now know it may be, by various factors that thus assume great sanitary importance. Not the least of these are temperature and nutrient conditions, and change in potency due to growth and development in certain animal or human bodies.

After infection or the reception of the contagium by a susceptible animal or person there is a *period of incuba-*

tion before the manifestation of the characteristic symptoms of the disease. This period is variable according to the disease or kind of germ, and during it the micro-organisms rapidly increase in numbers and in their consequent power for evil.

After the pathological process is well under way we shall probably find one of two conditions existing, viz,. that "in which the blood is the chief field of activity of the organisms,"[1] and the vessels of the victim are swarming with the microbes—in other words, a true *septicemia;* or else one in which "the poisonous results are not necessarily accompanied by the growth of organisms in the tissues," these latter, in all likelihood, not extending beyond the lymphatic glands nearest to the point of inoculation—*i. e.*, a *toxemia.* A good example of the former condition is furnished by a case of anthrax or of pyemia, and of the latter by diphtheria. However, we shall find in either condition that if we isolate the peculiar product or toxin of the specific germ, either from artificial growths upon or in culture-media, or from the blood or tissues of an animal sick or dead of the disease, and inoculate this into a susceptible animal, the general symptoms and results produced are practically the same as in an ordinary case of the disease. This goes to prove that the products of pathogenic organisms are toxic in character and harmful to the tissues, either locally or generally; that each of these toxic products gives rise in susceptible animals to characteristic symptoms which, taken together, constitute a specific disease, and that infection must be accordingly a biochemic and toxicological process. Another point to note just here is that these toxins are apparently harmful to the microbes themselves whenever they exceed a certain amount, as is shown by the fact that most of the infectious diseases are self-limiting, and by the cessation of growth and even the death of the germs in the various culture-media after a certain length of time. It is but

[1] Abbott, loc. cit.

fair to state, however, that there are other possible explanations of this latter phenomenon, viz., an increase in the resistance of the infected body to the action of the germs and toxins, or, as in the case of culture-media, the marked change in reaction caused by the microbial products.

Nothing that has been said in the foregoing pages should cause the reader to infer that all infectious diseases are caused solely by bacteria. Although the maladies due to the latter have thus far attracted the earlier and greater attention and study, a number of transmissible affections are now known to be due to animal organisms, and it is probable that still others will be added to the list. But whether a disease be due to bacteria, protozoa, or microbes of a higher classification, the general principles stated above will serve to give an understanding of their nature and mode of causation.

CHAPTER III.

TRANSMISSION OF DISEASE.

It would be interesting, were it within the scope of this work, to outline the various theories and beliefs as to the origin and cause of disease from the earliest times, when it was considered a punishment by the gods or an affliction of demons and evil spirits, or when, later, it was ascribed to malevolent aspects and conjunctions of the planets and other astronomical bodies, to abnormal "vapors" and "humors" of the patient's body, to miasmatic emanations from the earth or to harmful states or conditions of the soil, to filth and putrefying material, etc. Even now we find the relic of the miasmatic theory persisting in the term *malaria* "bad air," although we know that the state of the atmosphere has nothing to do with the cause of the disease, and many of religious mind still look upon sickness as a "dispensation of Providence," a view, perhaps, which we should not contest if we consider ill health as a penalty for the violation of Nature's laws and for the failure to avail ourselves of the knowledge concerning them that has been vouchsafed us.

This volume, however, has more to do with the ideas and practical information of the present day, established, as we believe, upon a scientific foundation in contrast with the superstitions, imaginings and theorizings of former times. Certain it is that the last half century or so has had in it such a testing and proving of the multitudinous phases and relations of disease as never occurred in all previous history, with the corresponding result that the advances in the conquest of human ills far exceed and over-shadow all salutary achievements of former times.

Since it has been well established that the causes of all infectious maladies are vegetable or animal microörganisms, and that the symptoms of illness and disturbances of the human body are due to poisons or harmful substances that these microörganisms create, the warfare against disease is much simplified and resolves itself into a study of these microbes, collectively and severally, of how they are transmitted to and enter the body, and of how we may combat them and fortify the system against their products. It is true that many discoveries, hitherto unthought of, have had to be made along these lines and many details worked out; also, that the end is not yet nor even in sight; but the progress has been unbroken and always leading to practical gain and victory.

One of the facts seemingly well established is that the "germs" that are the cause of human ills chiefly have their habitat in the human body and are not apt to survive long apart from it; that is, that most cases of infectious sickness are transmitted from one individual to another more or less immediately and are not likely to have carried on for long an active existence in the outside world. Some exceptions, of course, must be made to this statement, for it is true that highly resistant spores of some germs, such as those of anthrax or tetanus, and perhaps occasionally some dormant germs may persist for a considerable time without the body, and also that some germs may be common to other animals, as those of tuberculosis to the cow or of bubonic plague to the rat. It is also possible that in the household or elsewhere some of these germs may find lodgment in such excellent culture media as milk or other food-stuffs and so multiply therein for a time, but even this saprophytic existence is generally limited because of the formation of hostile products that interfere with their further growth and usually destroy them entirely. The human being has, in the main, its own special ills as distinguished from those of other species, and the causes of these are, as it were, hot-house plants and animals that

do not thrive well in the cooler temperatures and, for them, the less abundant food-supply of our environment.

Nevertheless, these pathogenic microörganisms are being so continuously thrown off by sick persons and by "carriers," and in such enormous numbers, that in the close intimacies and relationships of modern social life everyone is in continual danger of receiving some of them upon or within his body before their vitality and power for harm is destroyed by extraneous influences. In fact, were it not for the skin and mucous membranes which, when intact, form a very efficient barrier against these germs, and also for the destructive power of our body-cells and juices, of which more will be said later, there would be far more sickness and of much greater severity than we now experience. As it is, a large part of our sanitary regulations is for the express purpose of destroying and eliminating these malefactors that, having left one body in which they probably caused harm of greater or less degree, are now ready to enter another to continue their evil work. Our rules for the protection of water and food supplies, purification and control of sewage and offensive wastes, the surgical treatment of wounds, control of food-handlers, and even the cleanliness of our own bodies, are all means to the end of lessening the risk of infection; that is, of the intake by ourselves of these evil-doing parasites from our sick neighbors.

It is so clearly recognized that a well-marked case of any of the infectious diseases is a source of danger to others because of the discharge and possible dissemination of myriads of disease germs, that public opinion demands the strict isolation of the patient during the infective stages of his illness and the careful disinfection of his excreta and of things with which he has been in contact and may have infected. But few realize that there may be many cases of transmissible disease that are so mild in type as never to be diagnosed or recognized, the patient going freely about in the community and possibly referring to his indisposition as "just a cold," "a bilious attack," or

"a touch of malaria" or "grippe." These are termed "missed cases" and because of their unrecognized character may be of more danger to the community than ones of greater severity that are closely quarantined and guarded.

Moreover, there are many individuals in good health and without any symptoms who carry about with them and disseminate more or less continually the causative organisms of one or other of these transmissible maladies, the so-called "carriers" whose control is one of the serious problems of modern public health administration. Many of these carriers have previously had the respective diseases but as many others have not, the latter being apparently immune to them and as unaffected by their microbes as by the others of non-pathogenic and harmless nature that we all carry about with us. One may be a carrier for a comparatively short time after convalescence or after taking in the germs, or may continue as one for years, even though persistent efforts be made to rid him of his undesirable and dangerous acquisition.

Lastly, it is well to note that there may be missed cases and carriers of practically all of the infections, although typhoid fever and diphtheria have hitherto had most attention in this respect, and that one or the other of these may serve to account for the origin of new cases or an epidemic whose source is otherwise uncertain.

The transmission of infective germs to the body may be either direct or indirect, and, under ordinary circumstances, must be in one of three ways; by penetration of the skin or mucous membranes, by inhalation into the respiratory tract, or by swallowing and consequent access to the alimentary tract. So we find that diseases of this kind can be grouped according to the usual manner of ingress of their respective causes; thus septicemia, erysipelas tetanus, etc., may result from wounds or penetration of the skin; colds, diphtheria, scarlet fever, measles, etc., when the nose and throat are infected, or tuberculosis, pneumonia, bronchitis and whooping-cough, when the

intake of germs goes deeper into the lungs, and typhoid and paratyphoid fever, dysentery, cholera, etc., when the organisms are swallowed with the food or drink. Also, the location or primary seat of the trouble may have much to do with the nature of the treatment when and after sickness occurs; but it must be apparent to every one that prevention is better than cure, and that it will be far wiser and more advantageous to stop the invaders from entrance by specially guarding the portals of entry indicated.

Fortunately this task is made the more feasible by the realization that in the vast majority of cases these diseases are transmitted in one or other of only five ways; viz., by contact, by air, by food and drink, by fomites, *i. e.*, by inanimate things, and by insects. And just as our knowledge of many of the specific diseases and their respective causes has become more definite and exact in recent years, so our ideas concerning the relative importance of these five ways of transmission have changed somewhat, and our preventive practice has been made more simple and efficient. Thus, we can keep our hands and bodies clean by avoiding harmful contacts, we can purify water and milk supplies and guard our food-stuffs, we can sterilize infected clothing, eradicate vermin, screen against flies and mosquitos, etc., and so protect ourselves rationally and without undue effort to a degree almost unhoped for but a short time ago.

Infection by Contact.—The relative frequency and importance of these methods of transmission of infection must vary with circumstances. Moreover, it will often be difficult to determine by just which method the transference occurred, and, when known, we may debate as to the proper classification. Thus, when a sick person or a nurse who has just attended the patient handles and contaminates food and so passes the infection immediately on to another, is the transmission to be recorded as by contact or by food? Or, when a child conveys a pencil or candy directly from his mouth to a schoolmate, is the

consequent diphtheria to be credited to contact or the thing conveying it?

According to Chapin,[1] both of these instances would come under contact infection, for "it is now recognized that the contact need not always be direct between the sick and the well, but some infected person or thing may act as intermediary." "The term contact infection as now employed means the transference of rather fresh infecting material from one to another. It does not necessarily imply actual contact between sick and well, but it does imply that there are no long intervals of time in which the infective materials may become dry and inert." "By fomites are usually meant infected objects which retain the infection for some time." Whether we accept this distinction of Chapin's or not, any consideration of the subject in all its phases must convince one that transmission of infection is more largely due to contacts, direct and indirect, than to any other means.

The reader should realize that the present conceptions as to the causation of disease are comparatively new and that relatively few of the population have adapted themselves to them. The great majority, although undoubtedly afraid of sickness when it is brought home to them, apparently do almost everything in their power to invite it, often going so far as to resent, ignore and violate all measures of protection, such as vaccination, quarantine, etc., that modern science suggests and that public health authorities endeavor to enforce. When we consider the personal habits of ourselves and our immediate friends, not to mention those of the multitude, we may get some idea of the enormous number of personal contacts we are continually making in our daily life and of the risks we run. No matter how carefully we may avoid the immediate presence of and relations with the sick the numbers of missed cases and carriers cannot be detected nor avoided.

There is no need to take up the specific infections one

[1] Chapin, C. V.: Sources and Modes of Infection, 1910, pp. 125, 170.

by one. We know that for practically all of them, except those like malaria and yellow fever that are transmitted solely by insects, the transference is almost always by contact or by contamination with the discharges of the body, nasal, intestinal, renal, etc. We know the opportunity for the transfer of saliva or of more offensive excreta, which, whether infective or not, are intensely obnoxious to every one of decent instincts and sensibilities; and yet how many of us are careful to wash our hands before taking food or after attending to the calls of Nature, or of avoiding the transfer to our own mouths of more-than-possible germs by unclean hands, drinking cups, pencils, etc. The term "pus-germs" applied to certain of the microbes that we have so commonly about us does not necessarily connate their origin, but it nevertheless indicates it as a frequent certainty. And if we do not scrupulously attend to these matters for ourselves, how may we expect them to be attended to by the others who associate and mingle with us in daily life, those who handle and prepare our daily food, who serve us with other commodities, who use the same conveyances and conveniences, whose paths cross ours again and again and whose contacts are with us in a hundred ways?

The writer is avoiding statistics because he has no desire to create a fear of others nor the avoidance of human relationships. We must associate with our neighbors, and if we take what are only reasonable precautions, the actual risks are not as great as they may seem. Curiously enough, the close association of individuals in large communities brings about in many a certain degree of immunity to at least some of the transmissible maladies. For example, city children, and especially those who associate together most intimately, have been found to have a considerably greater immunity to diphtheria, as determined by the Schick test, than those from rural or sparsely settled neighborhoods, and not only children but adults from the latter districts are often more seriously affected by other contagions than are those from more

crowded sections. This is probably because a massive dose or a fairly large number of germs is necessary in most cases to cause a frank manifestation of disease, and the children of the crowded areas in their very intimate and unrestrained associations are continually receiving relatively small numbers of the specific organisms and so are gradually building up a positive immunity to the maladies to which they have been exposed. Larger doses of infective material, of course, would mean either "missed cases" or a recognized attack of the disease with later immunity in case of survival.

From what has been said it must be evident that we can do much to protect ourselves. We owe much to Chapin for making us appreciate the importance of this matter of contact infection, as he has done through many years of insistent writing and teaching and as one among the first to sense its bearing upon human welfare. To quote him again.[1] "If contact infection is the chief mode of extension of the contagious diseases, then defense against them becomes more largely a personal affair than we have been taught. We do not have to rely chiefly on the municipality for our protection, awaiting forced isolation, hospital construction, disinfection and the like, but can largely protect ourselves by keeping our fingers out of our mouths and also everything else except what belongs there. It may not be possible to prevent all contagious sickness in this way, but some can be avoided, and perhaps most of it. Contact infection is avoided by personal cleanliness, and personal cleanliness is demanded by decency, good manners and refinement, as well as by hygiene. It is not much trouble to be decently clean and it is not very expensive." "Formerly air infection was chiefly feared; now it appears that contact infection is of prime importance. Formerly dependence was put upon the State, to isolate and disinfect; now it appears that the individual can protect himself, and as easily

[1] Loc. cit., pp. 164, 166.

protect others if he chance to become infected. It is usually comparatively simple so to live as not to allow the secretions of others to come in contact with one's own mucous surfaces, and it is easy, and should be considered immoral, to allow one's own secretions to be so placed that they may infect another. Personal cleanliness is less expensive than municipal cleanliness and is within the reach of all."

Infection by Air. –One of the remarkable features of the "new" hygiene is the change of opinion concerning the influence of the atmosphere upon health, both as regards the problems of ventilation and the causation of disease. Where formerly much consideration was given to the composition of the air we breathe, the attention is now directed to its condition; and whereas for perhaps hundreds of years the atmosphere was looked upon as the chief source or bearer of contagion, it is now shown to be of least importance in that respect.

Probably no one can tell how long ago it was that mankind first realized that certain diseases were conveyed from the sick to the well or from without the body, and that the causes thereof were invisible and impalpable. How natural, therefore, to assume the evil to reside in the breath of the sick or in the miasms of the earth, in mysterious "vapors" and the like, and to make the air, itself invisible, the carrier if not the actual cause of the various infections! So deeply has this been ingrained in the common consciousness that much of it remains in the popular beliefs and practices of today. Even now we hear frequent warnings as to the dangers of the night-air, of the fogs from swampy places, etc.

But the modern tendency to put everything to the test has resulted in the discovery that not only are the various contagions simply animate microscopic organisms, but also that under ordinary conditions they cannot survive long, be carried far, and, in fact, rarely are transmitted through the air from one person to another for any great distance. Exposed to light and the drying influence of

the atmosphere, these germs quickly die if by themselves, and if attached to dust particles, as may be more likely, are carried down by gravity and have their existence only slightly prolonged, except under the most favoring circumstances. It is true that experimentally or where the atmosphere may be laden with much germ bearing dust, as in certain occupations, infection may be caused, but such conditions are unusual in ordinary experience. It is also true that highly resistant spores of some of the pathogenic microbes might persist for a considerable time in the air or dust, but with the exception of occasional cases of anthrax in a very few trades, we rarely find the diseases caused by such spores to be due to air transmission. So, we have come to believe that atmospheric infection, except in rare and unusual circumstances, can only take place at short range, and that even here it can be prevented by simple and reasonable precautions.

There seems to be no question that droplets of saliva or moisture may be expelled for a short distance from the mouth or nose in coughing, sneezing or even by forcible speaking, and that if the propelling individual is an infected case or carrier, that these droplets may carry the specific germs of the disease. This forms a reasonable explanation for the possible transmission of colds, influenza or pneumonia, and possibly of tuberculosis, diphtheria, scarlet fever, measles or other infections whose microbes may be present in the secretions of the nose and throat, and it is also the basis of the common-sense rules that, for the sake of safety as well as decency, the mouth and nose should be covered or the face turned aside when coughing or sneezing in the presence of others, and that for our own protection we should avoid unnecessarily associating with those who have any of these maladies, and especially we should, as far as reasonably possible, keep out of crowds and closely packed assemblages or conveyances during the prevalence of an epidemic of any of these diseases.

For a long time smallpox, one of the most contagious of diseases, was considered to be especially transmissible

by air, the risk of infection extending to at least a mile in the vicinity of smallpox hospitals; but while some records show that there was a higher incidence of the disease in the neighborhood of these "pest-houses," as they used to be called, this was probably almost entirely explainable as due to contact infection, as modern tests show practically no support of the theory of atmospheric infection in this regard. There seems to be some ground for the opinion that occasionally the contagion of smallpox may be conveyed through the air for very short distances, but scientific evidence of this is lacking and the opinion only persists for lack of a better explanation. Granting an occasional infection of this kind as a possible exception in the case of so contagious a malady as smallpox, it is evident that infection by air at long range must be a rare occurrence, if it ever happens, and therefore of slight importance as compared with other modes of transference of the same disease.

On the other hand, the possibilities of infection caused by the propulsion for short distances through the air of droplets from sick persons or carriers by coughing or sneezing cannot be ignored, and of even greater importance are the air hazards of certain occupations in which infective dust is more or less freely and frequently disseminated in the atmosphere. In such occupations the danger of infection may be real, and warrants the provision for the protection of the employees concerned of adequate ventilating apparatus, respirators, etc., just as in other occupations characterized by poisonous dusts and gases.

Infection by Water and Food.—Reference has already been made to the fact that the causative organisms of certain diseases are thrown off in large numbers in the excreta of the body. The frequent opportunities for the pollution of natural water supplies, both public and private, by such human refuse indicate, therefore, not only the possibility but the very great probability of infection by water being a common means of disease transference. Not only do numerous instances confirm

this, often with the most positive experimental proof, but the almost universal experience that wherever a public water supply has been purified or improved there has been a prompt lessening of the incidence of what are called the water-borne diseases and an improvement of the public health in general, leaves no room for questioning the importance of this phase of the subject.

Naturally the diseases that usually affect the alimentary tract, such as typhoid and paratyphoid fever, dysentery, cholera, etc., will furnish the most numerous and striking examples of this mode of infection, the literature on sanitation for the last forty years being full of illustrative instances of it. But more remarkable as evidence and in interest is the conquest of these maladies in centers where they were formerly among the chief sources of sickness and death. Thus, in seven[1] of the larger cities of the country the reduction within fifteen years in the death-rates for typhoid and paratyphoid fever indicates a saving in 1922 of almost 3700 lives and probably ten times as many cases of these diseases, the chief cause of the reduction in each of these cities being the improvement and purification of the public water supplies.

A general study of private water supplies will show many opportunities for and frequent occurrences of infection transmitted by them. Such cases are usually of the intestinal group, and while there is always the possibility that the germs of other diseases may be carried into the body in this way, such instances are not common, possibly because they cannot long withstand the hostile conditions in polluted waters. It is now known that neither malaria nor yellow fever can come, as was formerly believed, from such a source, but cisterns, tanks, reservoirs, etc. may be the breeding places for the mosquitoes that are the hosts and carriers of the respective germs of these diseases. Nevertheless, in spite of the foregoing exceptions, the injury to health due to impure water makes

[1] New York, Chicago, Philadelphia, Cleveland, Boston, Baltimore and Pittsburgh.

an alarmingly large total in the course of a year, no matter how the injury may be reckoned or estimated.

Infection by food is important not only because the food itself is more likely to be the carrier of germs of other maladies in addition to those of the intestinal group, but because it is, as a rule, a favorable culture medium for many of the harmful microbes. Moreover, while water is carried more or less directly to the consumer from its source by pumps, piping or city mains, almost all food is subject to frequent handlings by numerous individuals, with a consequently increased likelihood of contamination from some of these, or by flies and other vermin, or by contact with infected things.

Milk especially, of all foods, is the one by which disease is most frequently transmitted. Not only is it the most universal food-stuff, but it may come from sick cattle, it may be handled by persons who are ill or carriers, be transported to the consumer in contaminated vessels, or, even within the consumer's own household, be charged in any one of various ways with dangerous germs and be so carelessly cared for that the germs, though few at first, may increase to numbers more than sufficient to infect one or many of the household. Again, for these same reasons, milk is the more likely to contain the microörganisms of tuberculosis, scarlet fever, diphtheria, etc., as well as typhoid fever and others of the intestinal group. Many authorities have noted numerous of these diseases as due to transference by milk, and individual cases of such infection come within the notice of almost every physician. Chapin says:[1] "Scarlet fever and diphtheria are certainly much more rarely transmitted by means of milk than typhoid fever. Although the percentage of typhoid fever, scarlet fever and diphtheria due to milk is small, the danger is a real one and the aggregate of cases not inconsiderable, and their occurrence should, if possible, be guarded against."

[1] Chapin: Sources and Modes of Infection, 1st ed., p. 289.

An interesting example of specific milk infection is that of Malta or Mediterranean fever, which is a disease of goats on the Island of Malta and the neighboring shores of the Mediterranean, and is transmissible to man by the milk of the sick goats.

Contrary to expectation, meat is not a frequent factor in infection, not only because few diseases of animals are transmissible to man, but also because meat is usually cooked and so subjected to a temperature sufficient to kill most of the disease-producing bacteria that may be present. Moreover, a large portion of the meat consumed in this country especially in the large cities, is subject to a careful, Federal control and inspection. Tuberculosis does not affect the muscular tissue, and the glandular organs or other viscera of infected animals are fairly certain to be cooked before using. "Ptomaine poisoning" or other disturbances due to the putrefaction or "spoiling" of meat do not come under the head of infections, however harmful they may be, nor, strictly speaking, do the diseases attributed to the higher animal parasites, such as the trichinæ and tapeworms. A few bacteria of the colon group may affect animals, and meat from animals thus infected may very rarely cause disturbing symptoms.

At times in recent years serious epidemics or local outbreaks of typhoid fever have been traced to infected oysters or other shell-fish taken from or that have been placed temporarily for "fattening" in sewage-polluted waters. A number of cases of this disease occurred almost simultaneously in the early part of 1925, in New York City, Chicago and Washington, D. C., and the source of infection was traced to oysters taken from polluted waters in the vicinity of New York and shipped by the same dealer to all three cities.

Articles of food like celery, lettuce, radishes, watercress, etc., that are usually eaten uncooked and that have come from fields fertilized with human sewage or sprinkled with polluted water have been known to transmit typhoid fever, a considerable number of cases from

this source sometimes occurring in an institution or local neighborhood.

Any other articles of food responsible for infection have probably received the germs in the course of handling or preparation by infected individuals or carriers, and not because of anything harmful being inherent in the particular food-stuffs involved. Or the food may have been contaminated by insects gaining access to it after they have been in contact with infected individuals or things, a phase of the subject that will be discussed a little later.

As it is, infection by water and food is responsible for a fairly large part of transmitted illness, and so is not to be lightly considered in any planning to reduce the prevalence of such illness.

Infection by Fomites or Inanimate Things.—Long before the germ theory became a matter of popular knowledge and acceptance, it was realized that sick persons gave off something that, under suitable conditions, transmitted their respective maladies to others. It was thus easy to surmise that the infecting matter or *contagium*, whatever its nature, might adhere to objects touched by the sick or contaminated by their excretions, and that such objects might be the means of conveying disease to others. There was, of course, plenty of confirmatory evidence to support such an opinion, especially as disinfection was virtually as yet an unknown practice; consequently, the belief in the common and frequent transmission of disease by inanimate objects or fomites became entrenched in the popular mind, and was strengthened rather than weakened when the discovery of various disease germs explained the true nature of the contagium or infectious matter that conveyed disease from one individual to another. So, the theory of the transmission of disease by fomites duly became the basis for the development of the thorough and elaborate methods of disinfection that became and have been an important part of our sanitary practice.

However, with the realization that the disease germs are veritable hot-house plants and tender animals, requir-

ing the warmth and other favoring conditions of the living body for their growth and multiplication, and that they quickly succumbed or only rarely persisted as saprophytes in the outside world, we have come to see that it is only under exceptional circumstances that contaminated articles retain their power of infection for any considerable time. And so, if we accept Chapin's contention that the indirect but immediate transfer of fresh contagion from the sick to the well is to be classed as contact infection, it is evident that infection by fomites is considerably lessened in importance in comparison with other methods of transmission, this importance being still further reduced by our more recent understanding of the rôle of insects as carriers of the microbes of disease. Thus, until, it was known that yellow fever could only be transmitted by mosquitoes that had bitten patients having the disease, it was universally considered that fomites were the chief agents in the transference and dissemination of this disease.

Nevertheless, there are cases in which this mode of infection cannot be ignored. Anthrax is all too frequently carried by infected hides, wool and hair, and tetanus is often a sequel of wounds contaminated by infected soil or clothing, since the germ-spores of these two diseases are highly resistant and may remain alive for a long time in the articles mentioned. Moreover, there is plenty of evidence that other less resistant disease germs may, under favoring conditions of darkness, moisture and a modicum of food, occasionally maintain life and virulence for a considerable time until again transplanted into susceptible human bodies.

If the germs of tuberculosis, typhoid fever, diphtheria, scarlet fever, measles, etc., are all sufficiently resistant to cause occasional cases in this manner, as seems very probable, we cannot ignore the possibility of similar infection in other diseases at times when the mode of origin would otherwise seem to be inexplicable. Perhaps we should have more of such cases if so many of us were not more or less immune to the respective germs, especially

when they are weakened in virulence and reduced in numbers by the adverse conditions and, for them, prolonged sojourn outside the human body.

Infection by Insects.—The appreciation that disease may be transferred from one individual to another by insects is of comparatively recent date—a little more than thirty years ago—for it was not until some time after the discovery of the nature of the causes of transmissible disease that even scientists and physicians began to realize how readily the specific germs might be carried about by these somewhat higher organisms that so frequently are found as nuisances and vermin in and about human dwellings. And although at various earlier times keen observers and thinkers, such as Beauperthuy in 1854, and Finlay in 1882, who tried to direct attention to a possible relationship between mosquitoes and yellow fever, had suggested such a mode of infection, the actual demonstration and acceptance of the germ theory was needed before we could have the general realization that these abundant and all-too-frequent invaders of our households were not only nuisances but also dangerous malefactors and menaces to health.

For some maladies this mode of infection is proved beyond a doubt; for others, it offers a reasonable explanation of the origin of many obscure cases and furnishes the basis for a new method of attack upon infectious diseases in general. Thus, whether we can prove the charge against all species of vermin or not, it is the part of good sanitation to make war upon them generally and to endeavor to eliminate them from our environment.

The discovery that insect carriers are the sole means of transmission of certain diseases makes it possible to plan such rational, comprehensive and effective campaigns of attack as to promise in the near future the very probable abolition of some of them as menaces to humanity. Yellow fever, which was formerly endemic in and the scourge of many tropical regions and often epidemic in our own country, is now confined within very narrow limits and will probably never again be a disease of much

moment or concern to the world at large. So, in a lesser degree as yet, with the plague which, although still prevalent in Asia, has ceased to be the scourge of Europe that it formerly and frequently was; or with typhus fever or malaria, both of which we may now feel are held fairly well in hand wherever a definite and well-sustained attack has been made against their carriers. In fact, it is only a question of time until these will be among the rare infections in most communities of a progressive civilization.

On the other hand, the campaign against the kinds of insect carriers that disseminate the germs of various diseases promiscuously rather than specifically does not, for obvious reasons, produce such marked or striking results, although it is well worth the efforts expended in its conduct. To rid a neighborhood of a certain kind of mosquito, for example, means a systematic search for and destruction of its breeding places by drainage, oiling, etc., and is a simpler proposition essentially than would be an effective attempt to destroy all the flies and other insect vermin in the same neighborhood. Thus the intelligent expenditure of a certain amount of effort would probably show a definite reduction in the incidence of malaria in the locality where it was applied, while the same amount of effort directed against insect carriers generally, although doubtless of great benefit to the community, would very likely not yield such positive evidence in respect to the reduction of the common infectious diseases because these have also other modes of transmission whose prevailing factors might readily counterbalance and obscure much of the good actually accomplished by the fight against insects. This, however, is no reason nor excuse for not prosecuting such campaigns wherever and whenever the opportunity offers and the means are available.

From what has been said, it must be evident that insect carriers of infection naturally divide into two classes—those that respectively transmit the germs of

but a single disease, some of these carriers also acting as hosts to the germs during certain stages in the development of the latter, and those that may carry the microbes of any infectious malady, these rarely, if ever, serving as special hosts because the germs have no special or peculiar phase of development in them.

Thus, we know that human malaria is transmitted only by one or, at most, two species of mosquitoes, yellow fever by another distinct species, dengue fever by a third, as well as by the malaria carrier and other rarer infections by still other species. Also, that typhus fever is carried solely by the body louse, which was also responsible for the spread of trench fever in the armies of the World War; that bubonic plague[1] is due to the bite of fleas from rats infected with this disease, the sleeping sickness of Africa to the bite of the tsetse fly, relapsing fever to one kind of infected ticks and Rocky Mountain fever to another kind, and so on.

On the other hand, flies and most, if not all, of the other insect vermin of our households and neighborhoods can and probably do carry the germs of such diseases as typhoid and paratyphoid fever, dysentery, tuberculosis, etc., finding the germs in the excreta of infected patients to which they have access and transfering them more or less directly to uninfected individuals. How often infection is caused in this way would be difficult to determine, but that it occurs more often than occasionally is probable from the number of cases for whose origin it offers a reasonable explanation. And it is not difficult to find the germs of these diseases on or in the bodies of insects for some time after they have been allowed access to the excreta from such patients. Regarding the transmission of diphtheria, scarlet fever, measles, etc., in this manner, the evidence is not so positive as it is for maladies

[1] The pneumonic type of plague, as distinguished from the bubonic or usual type, is probably transmitted almost solely by droplet infection from or by direct contact with individuals suffering with this particular form of the disease, which rarely occurs except in certain epidemics.

more directly affecting the intestinal canal, but the possibility of such infection should be sufficient warrant for all reasonable precautions against it. The very simple experiment of allowing flies, cockroaches or bedbugs to walk over sterilized plates of culture media will show by the growth on the plates within a day or so that any of these insects carry and leave wherever they go large numbers of various kinds of microörganisms, so that there can be no doubt of the physical possibility of their carrying disease germs in this manner.

The fact that the breeding places and common habitat of many of these insect pests are in accumulations of filth and human wastes only emphasizes the importance of constant warfare against them, and the realization of the frequency with which they invade human dwellings and other occupied places should justify every effort to exclude and destroy them. Probably the common house flies are the most numerous and collectively do most harm by infecting milk and other food-stuffs, but it should be remembered that there are more than fifty other species of flies, some of which have been proven capable of carrying germs and others possibly doing so, and that other household vermin, such as cockroaches, bedbugs, etc., are not above suspicion in this respect. As a matter of self protection, mosquitoes are to be kept out of our dwellings by proper screening and their breeding places destroyed by draining, oiling, etc., especially if there be any evidence or risk of the presence of malaria, yellow fever or any of the mosquito-borne diseases in the district.

In addition to the germs being carried on the bodies and feet of house-flies and other insects, as demonstrated by the experiment indicated above, there is also evidence that they may be ingested by the insects and later distributed by means of their excreta or regurgitated saliva, the germs being found in these and in the bodies of the insects even several days after the latter had fed upon infected matter. Hence actual cases of illness are not needed to demonstrate the probability of their transmitting

disease, although there is plenty of both laboratory and clinical evidence to make the probability a certainty.

Much might be written, did space permit, of interesting features pertaining to this kind of infection. Thus, with the "biological" carriers, as those are called in whose bodies certain phases in the life cycle of the infectious microbes must occur before infection is possible, we find that several days must elapse after a mosquito has bitten a malarial or yellow fever patient before it can transmit the disease to another individual, its bite in the meantime being harmless as far as infection is concerned. Also, in the case of relaping fever and of Rocky Mountain fever the infected ticks may and often do transmit the germs to their ova without destroying the vitality of the latter, so that, when these develop, the new generation of young ticks is fully capable of infecting susceptible individuals or animals that may never had any contact with the parent ticks or relation to the original source of infection.

CHAPTER IV.

IMMUNITY.

Having obtained some knowledge of the exciting causes of infectious diseases, of how they act and how they are transmitted, another important consideration is to see whether we can discover how to prevent the incurrence of these diseases by the well and to antagonize or check the further action of the cause in those already infected. It is well to disinfect and to destroy disease germs whenever and wherever it is possible to do so, and at the same time to prevent in any manner their transference from unknown or inaccessible sources to susceptible persons, but it is still better so to strengthen and fortify the human body that the microbes, even though received into it, will be unable to do it harm. This is the essence of the "new hygiene, viz., to increase the capacity and power of the body to adjust itself to harmful external conditions or influences, and thus to withstand more readily the active causes of disease. Naturally our first desire would be to secure a permanent insusceptibility, if this might be had without too great risk or discomfort; but since with our present knowledge, this is rarely possible we must endeavor, especially when the danger of infection is imminent, to secure the greatest possible immunity within brief time limits even though the protection be only temporary or incomplete. Occasionally we find individuals that possess extreme natural immunity to certain maladies; observation shows that most well persons have fair protection in the case of ordinary exposure to infectious matter; and further investigation teaches that this protection is affected by such factors as one's state of health, occupation, age, or

diet, or by injuries, drugs, fatigue, exposure to heat or cold, etc. But our desire is to know how to provide a positive immunity against each infection and for all persons. That we have the means of producing such protection with respect to one disease is well shown by the history of vaccination, and to another by the results obtained by the inoculation of many thousands of soldiers in the recent world war against typhoid fever and its congeners; in addition, the work of many investigators in recent years indicates that the promise of similar results in regard to many other maladies is by no means vain. Certain it is that many human beings and animals have been rendered apparently immune to other fatal diseases, and the indications point to the probability that the human race will shortly have the same protection against most of the transmissible maladies that it now has against smallpox.

"At present the chief successes of immunotherapy have to do with the bacterial diseases, but experiments show that the same principles prevail among the protozoan infections, and there is little doubt that as our knowledge of these maladies becomes amplified the benefits of immunological research will be found to be available in them. It is now universally admitted that microbes are pathogenic or disease-producing by virtue of certain poisonous metabolic products.

"These toxic products, embracing what have been variously described by different authors as toxins, toxalbumins, and bacterioproteins, are all of proteid nature. Their physiological effects vary greatly among themselves, but they all have in common, and together with practically all heterologous proteid substances, the property of stimulating certain antagonistic physiologico-chemical reactions on the part of higher organisms, and hence are included in a group of miscellaneous character, to which the name *antigen* has in recent years been applied. By antigen, therefore, is meant any substance capable of stimulating an antagonistic reaction when introduced

into the body of one of the higher organisms. The nature of the reaction is, in itself, unimportant, so long as its tendency is antagonistic to the antigen."[1]

Moreover, these antagonistic reactions caused by antigens result in various *antibodies*, such as antitoxins, antimicrobins, etc., which not only serve to protect the bodies in which they are formed against the harmful influence of the antigens, but also, being carried in the blood of such bodies, can be transferred to others and thus give the latter the same protection. This is one of the great discoveries incident to the prevention of disease and has been of incalculable value to humanity already. What it will be in the years to come one can scarcely presage or dare to hope.

Just here it may be well to consider several theories that have been advanced in the attempt to explain the phenomena of immunity. Of these, two were disproved long ago, viz., the *exhaustion* theory of Pasteur, which was that the pathogenic germs in their process of growth in the body removed some material from the latter necessary to their existence; and the diametrically opposite *retention* theory of Chauveau, which was that the germs produced some substance which gave immunity as long as it was retained in the tissues. On the other hand the *phagocytosis* theory of Metchnikoff and the *humoral* theory of Büchner have been practically established if they are considered as being duly qualified by the results of the research of later years.

The phagocytosis theory is, that "immunity against infection is essentially a matter between the invading bacteria on the one hand and the leucocytes of the tissues on the other; that during the first attack of the disease the white blood-corpuscles gain a tolerance to the poisons of the bacteria, and so are able to resist the next incursions of the enemy and to attack and destroy the latter," the

[1] McFarland in Modern Clinical Medicine, Wilson and Salinger, 1910, pp. 909 and 910.

fact that they really ingest and digest the latter being readily demonstrable by the microscope.

Büchner apparently showed that the blood-plasma, especially that of immune animals, is bactericidal to many virulent germs, and he attributed this effect to the presence in the fluid of certain proteid substances akin to globulin. These he termed *alexins*, from a Greek word meaning to protect. Further, he believed that they act chemically in causing death of the disease germs, and that the increased amount of alexins in the blood of those who have acquired immunity is brought about by a stimulation or "reactive change" in certain cells due to the presence of the bacteria or their products. Moreover, this humoral theory serves to account for the natural immunity possessed by some individuals and animals, their body-juices presumably containing, through some cause or other, an extra quantity of the protective proteids.

But an essential factor in securing immunity is the power of the body to resist or endure the poisons produced by the disease germs, something fully as important as its ability to destroy the infecting organisms. Consequently there is another theory—that of the *antitoxins*—which, in view of recent developments and the fact that it is capable of immediate practical application, is one of the most important thus far proposed. It is well known that the human system has the power of tolerating or accommodating itself to the action of almost any toxic substance—provided the latter be administered at first in sufficiently minute doses and then gradually increased—until it can in time withstand quantities that would quickly prove fatal to one unaccustomed to the poison. Ehrlich has further shown that with the toxic alkaloids of certain higher plants, after a certain degree of tolerance is attained the administration of the drug may be much more rapidly increased, and that while up to this point no apparent change occurs in the body-fluids, now, when the tolerance becomes so much increased, a new

substance is produced in the blood which is capable of neutralizing the poison in not only the person or animal under experimentation, but also in others into whom it may be introduced. Further investigations have shown that this same production of antidotal or antagonizing substances may be brought about by the slow administration of the toxins of pathogenic bacteria—something not hard to understand when we remember that the bacterial toxins are just as much the products of plant-life as are the alkaloids that Ehrlich used. On the other hand, the antitoxins, as the substances antidotal to the toxins are called, have been found to be albuminoid in character and similar in composition to the nucleins. In fact, attempts have been made to employ the latter in place of or in conjunction with the antitoxins, with results that have not been altogether without success.

Much credit must be given to the labors of Behring, Roux, Kitasato, Haffkine, and others for the development of practical methods of using the antitoxins, methods which are now recognized as eminently proper and even superior to any others in the treatment of some of the most virulent diseases. The great reduction in the mortality from one disease alone—diphtheria—already attained through the application of this treatment almost exceeds expectation and belief, and the results with respect to tetanus, cholera and other deadly maladies have been likewise brilliant and add further glory to this new science of bacteriology.

More recently Wright demonstrated that the blood contains certain substances which can so affect disease-producing bacteria that the leucocytes will more readily destroy them by phagocytosis. These substances, which he calls *opsonins*, vary not only in quantity in different persons, but apparently also in quality, there being probably a specific opsonin for each kind of pathogenic organism. Moreover, it has been found that in many cases the amount of influence of a given opsonin can be increased in the blood by appropriate inoculation of sterilized bac-

teria of its particular kind; and, secondly, that by determining a patient's *opsonic index* for a particular disease we can approximately estimate his power of resistance or degree of immunity to that disease. The opsonic index of an individual is the ratio between the phagocytic power of a certain number of leucocytes—as indicated by the number of bacteria taken up in a given time when acted upon by a unit of his serum—and the power of the same number of the same kind of leucocytes when the bacteria are acted upon by a unit of serum from a normal and healthy person.

To some it may seem that either the humoral or the antitoxin theory is identical with the discarded retention theory of Chauveau; but it should be noted that according to the latter the invading microbes themselves produce the antidote or antagonizing substance, while Büchner's theory attributes this production to the integral cells of the body, which furnish the alexins normally in minute quantities to the blood, and asserts that the latter are germicidal to the bacteria themselves; and, on the other hand, the antitoxins, though produced like the alexins by body-cells, probably act chemically in neutralizing the bacterial poisons, and are dependent upon the prior presence in the body of the toxins, being a result of its acquired tolerance to the latter. With alexins or antitoxins it is evident that the immunity will last only so long as these substances remain unchanged in the blood.

However, there is no reason why the phagocytosis, humoral, antitoxin, and opsonin theories should not mutually support rather than tend to discredit one another. There seems to be good evidence of the phenomena upon which each of them is based, and even with our present incomplete knowledge of the blood and its component parts, it is not difficult to conceive that while the alexins, and later the antitoxins and opsonins protect the leucocytes by weakening the vitality of the microbes and neutralizing their products, the leucocytes thus guarded and in full vigor attack and make way with the bacteria,

which have lost their power for evil. In other words, if the production of the toxins of an infectious malady is not too rapid, all four of these agents may combine to overcome the enemy, and not only to limit the disease, but also to give subsequent immunity for a more or less prolonged period.

Much consideration has been given to the so-called *lateral chain theory of immunity* suggested by Ehrlich in 1897, since it serves better than anything else to aid in the solution of many of the problems of this abstruse subject. It is primarily dependent upon the well-known fact that many poisons, including the bacterial and similar toxins, have a specific attraction toward and action upon certain cells of the body. Ehrlich assumes an extremely complicated cell protoplasm with many affinities for combination with external substances. These affinities may be hypothetically and graphically represented as material parts of the cell, say as slight protoplasmic protrusions on the contour of the cell-wall, and these affinities thus materialized he terms "lateral chains" or *receptors*. Now according to their particular and respective affinities the receptors attract to themselves the various molecular food particles that the cell needs, it being possible, however, for one receptor to have an affinity for several kinds of molecules. Such molecules capable of attraction and combination with the receptors are termed "haptophores." Accordingly, haptophores of a poisonous nature that have either entered or been created in the body may combine with certain receptors of a given cell, and if of sufficient number and virulence may altogether check the nutrition of and destroy the cell; but if not sufficient in number and toxicity, the irritation caused by the harmful haptophores only stimulates the cell protoplasm to the formation of new receptors of that particular kind in order that its nutrition and function may be maintained; and it is conceivable that through continued or repeated irritation the cell may create many more receptors than it needs, which may

subsequently be separated from it and thrown off into the surrounding fluids and spaces of the body as particulate bits of a definite chemical substance with its own specific affinities and properties. Eventually, then, there may be prepared enough specific and extra receptors, either attached to or dissociated from the cells, to attract and unite with all the toxic haptophores likely to be present in the body fluids, now or later, so that the cells are no longer unduly irritated, but perform their functions in a normal manner. So, also, cells primarily lacking the appropriate receptors are immune against the molecules of a given poison.

Ehrlich's theory goes further, and, taking into consideration the known production in the animal body under stimulation by particular foreign and harmful cells, such as bacteria, of specific substances capable of dissolving and destroying the invading cells, assumes the production of linking molecules or *amboceptors* that will bring into contact and union the solvent or *lysin* and the particular cells which it is to destroy.

Thus we can appreciate the identity of the receptors and antitoxins, and that the lysins just mentioned correspond to the alexins of Büchner.

"Acquired immunity depends upon the regeneration of receptors to compensate for those thrown out of service by union with useless haptophores. The increasing immunity characterizing immunization depends upon the regeneration of an unlimited number of receptors, so that the cell can provide for the ever-increasing number of haptophores brought to it and still have enough receptors remaining to carry on its own nutrition."[1]

MacFarland has prepared the following scheme to show the present state of knowledge regarding immunotherapy, its purposes and possibilities.[2]

[1] Medicine, June, 1903, p. 450.
[2] Modern Clinical Medicine, Wilson and Salinger, 1910, p. 918.

IMMUNOTHERAPY.

I. Prophylaxis.

1. Immunity Induced Before Exposure to Infection.

A. *Active Immunity.*

a. By inducing a mild attack of the disease by the use of a carefully selected virus.	Inoculation.	Variola, yellow fever.
b. By the employment of a much-modified virus.	Vaccination (Jenner).	Variola.
	Vaccination (Microbination) (Pasteur).	Chicken cholera, anthrax, quarter evil, cholera, plague, typhoid.

B. *Passive Immunity.*

1. By injection of antitoxic serum.	Antitoxination.	Diphtheria, tetanus.

2. Immunity Induced After Exposure to Infection and During the Incubation Period of the Disease.

1. By the employment of comminuted tissue containing the essential cause of the disease in an attenuated form.	Microbination.	Rabies.

II. Treatment.

1. By Producing Active Immunity.

A. *By Aiding the Bacteria-destroying Mechanism.*

a. By employing killed or modified cultures to excite phagocytosis through increase of opsonins, etc.	Microbination.	Acne, furuncle, carbuncle, chronic suppuration, chronic gonorrhea, typhoid, Malta fever, tuberculosis.

B. *By Aiding the Toxin-enduring Powers.*

b. By stimulating antibody formation during the course of a prolonged infection.	Toxination.	Tuberculosis, lepra.

2. By Producing Passive Immunity.

A. By injecting antitoxic serum to neutralize toxins produced in the course of the infections.	Antitoxination.	Diphtheria, tetanus, snake-bite, hay-fever, plague tuberculosis, lepra.

B. By injecting antimicrobic serum to aid in the destruction of the microbes through the action of the specific amboceptors.	ANTIMICROBINATION.	Cerebrospinal fever, gonorrhœa, plague, dysentery, pneumonia, erysipelas, scarlet fever, puerperal fever, typhoid, anthrax tuberculosis.

Method of Preparing Diphtheria Antitoxin. — Within the span of a generation the antitoxins have been discovered, tried, and practically adopted by the medical profession of the civilized world as a safe and efficient means for the prevention or the alleviation and cure of several of our most dreaded diseases. A short account of the usual method of preparing the antitoxin of diphtheria will therefore probably not be uninteresting.

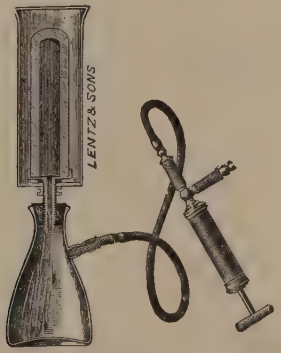


FIG. 13.—Filter for removing bacteria from fluid culture-media.

In the first place, it is necessary that the toxin of the disease should be produced, which is commonly done by growing the specific organism in peptone-bouillon. When this has attained a powerful and definite virulence, as determined by its effect on small animals of known weight, the organisms are destroyed by some germicide,

such as trikresol, or more commonly are removed by careful filtration from the bouillon which holds the toxin in solution. A small quantity, say 0.1 cc. of the filtered bouillon is then injected into a large animal, such as the horse, which should be in good health, and which preferably should have been tested previously by inoculations of tuberculin and mallein to eliminate the possibility of the presence of tuberculosis, glanders or any other diseases that are communicable and dangerous to human beings. After the injection of the toxin, the animal manifests for a few days the disturbances peculiar to the disease in question but usually in a minor degree, since the dose was purposely quite small in proportion to its weight. As soon as recovery is evident another inoculation of an

FIG. 14.—Hypodermic syringe for administering antitoxin.

increased dose is made, and so on until experiment shows that the animal can withstand practically an unlimited quantity of the toxic bouillon, and certainly an amount which would have been quickly fatal before the first inoculation. This is evidence that the antitoxin has been produced and that it exists in approximately sufficient degree in the blood-serum, but positive confirmation is secured by introducing a little of the horse's blood into a guinea-pig or other small animal that has received a surely fatal dose of the toxin bouillon. If it survives, a quantity of blood is then drawn with the strictest antiseptic precautions into sterile flasks from the jugular or other large vein of the horse, the latter returned to its quarters, and the blood set aside in a cool place to

coagulate. This done, the clear serum containing the antitoxin is drawn off and to it is added a small quantity of trikresol or other harmless preservative.

It is now necessary to determine the strength of the serum. The fatal dose of toxin for guinea-pigs is readily found by experiment. Behring therefore suggested in the case of diphtheria antitoxin that the immunizing unit be taken to be 1 c.c. of a serum of which 0.1 c.c. would prevent edema and death in guinea-pigs when injected simultaneously with 10 times the fatal dose of the toxin. In other words, the immunizing unit was to be sufficient to overcome 100 times the amount of the toxin required to kill a guinea-pig. The antitoxin serums now administered are, however, much stronger than this normal serum of Behring's, the amount usually injected being equivalent to from 500 to 5000 or even more immunizing units, the weaker strength being used for immunizing those who have not as yet incurred the disease.

Much depends upon the early use of the specific antitoxin in cases of diphtheria, and probably also in the other diseases for which this method of treatment is found valuable, for it is not to be supposed that the remedy has any power to repair the organic lesions which have already been caused by the action of the powerful toxins, and if the latter are permitted to act for a considerable time before being neutralized by the respective antitoxins, fatal or incurable damage may be done.

That the antitoxin treatment is invaluable cannot be doubted. The statistics of Prof. Welch, of Johns Hopkins Hospital, founded on a very large number of diphtheria cases, "show an apparent reduction of case-mortality of 55.8 per cent.," and where the application was made in the first three days of the disease the mortality was only 8.5 per cent. in over 1100 cases as against a mortality of 30 per cent. or higher under former methods of treatment.

Still more striking have been the mass results of the past quarter century not only throughout this country but wherever this protective treatment has been used.

With the mortality-rate in the registration area dropping from 70.1 per 100,000 of population in the pre-antitoxin year 1890, to 43.3 in 1900 and continuing on down to 14.6 in 1922, we have the positive evidence of one of the most notable achievements in medical science. When we appreciate that the area giving this latest rate now represents over 85 per cent. of our population, it is prob-

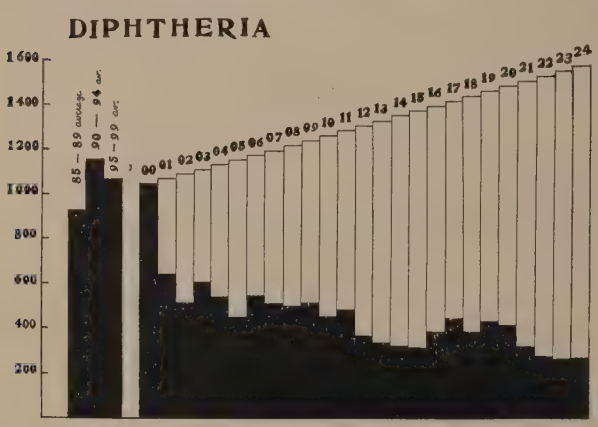


FIG. 15.—Chart showing reduction in diphtheria death-rate in Philadelphia due to use of antitoxin. This represents a total saving of over 21,000 lives. The white columns indicate the deaths that would have occurred if the rate of 1900 had not been lowered.

able that, even when compared with the 1900 rate, there is a human saving of upwards of 31,000 lives annually, and which rises to over 60,000 if we go back to the rates before we had the antitoxin. The results have been so positive, the advance so progressive, and any other changes from the previous methods of treatment of the disease so slight as to preclude any possibility of doubt that the gain must be attributed almost entirely to its adoption

and use, or as to the wisdom of employing it both as a remedy and as a prophylactic.

The immunity secured by the use of an antitoxin is almost immediate, an advantage often of the greatest importance; but since it is passive, the antitoxin having been developed outside of the person protected, it is more or less transient, and the inoculation must be repeated at intervals, or when danger of new infection is imminent. The same remarks apply to the use of *antimicrobin*, the product resulting from the gradual introduction of the bodies of killed bacteria rather than their toxins into susceptible and suitable animals. This latter gives rather a bacteriolytic form of immunity, and thus far is not so satisfactory as that due to antitoxin.

On the other hand, immunity that is acquired actively, either by accident or by deliberate experiment, is slower in developing, but much more likely to be permanent. It is a result, as we know, of most of the spontaneous infectious diseases, though its duration in some cases is briefer than we desire. It may also be secured by *prophylactic infection* or by *prophylactic intoxication*. In the former we may use virulent infective matter in much reduced doses or quantities, or better and more safely as far as man is concerned, some form of attenuated virus may be employed, the infecting matter having been modified by development in animals of another species, or by heat, light, drying, electricity, growth in unfavorable media, etc. As an illustration, we have the modern vaccine virus derived from the cow which has entirely supplanted the former direct inoculation of matter from the human smallpox patient. As for prophylactic intoxication, we may use either the dead bodies of the infectious bacteria, as has been done by Haffkine in his work against plague and cholera, and more recently in antityphoid inoculation, or the products of the organisms derived from artificial cultures, as indicated in describing the production of antitoxin and as is now employed in the so-called toxin-antitoxin method for preventing diphtheria.

Some years ago Schick demonstrated that by the introduction of a very small amount of diphtheria toxin into, not under, the skin of the forearm the susceptibility of an individual to that disease could very probably be determined, just as von Pirquet had previously by means of tuberculin been able to show, not the susceptibility, but the actual latency of tuberculosis in his patients. In the Schick test, a small reddened area a centimeter or more appearing about the point of inoculation within forty-eight or seventy-two hours and persisting for some time is considered good evidence of susceptibility.

If now a somewhat larger amount of the toxin guarded by sufficient antitoxin to ensure that no harm may come to the individual from the toxin, be inoculated beneath the skin, and if this be repeated twice at intervals of a week, the subject will gradually develop a much more permanent immunity than by the administration of antitoxin from the horse, and after several months, when again tested by the Schick method, will in all probability show no reaction to the toxin. Both the Schick test and the toxin-antitoxin prophylactic treatment have been administered to many thousands of children in New York City and elsewhere with no harmful results of any moment, and it now seems certain that we have in these methods the means of eliminating diphtheria from the list of prevalent and serious diseases.

Another recent and marked series of achievements are the discovery of the cause of scarlet fever by Drs. George and Gladys Dick, the development of a diagnostic test for this disease by them very similar to that of Schick for diphtheria, and the inauguration of what seems to be a safe and practical means of immunizing the susceptible against the malady. With both diphtheria and scarlet fever under our control and, like smallpox, in the list of rare diseases that we may avoid if we will, what a load will be lifted from many a parent's heart!

Vaccination. — Within the last few years there have been many epidemics of smallpox throughout the whole

country, the extent and spread of which have been due to a very general neglect to secure the protection afforded by vaccination.

More cases occurred in the United States in 1924 than in any other country in the world, the data being 55,528 for this country, 46,374 for British India, and 24,607 for European Russia. Such a record is not only disastrous from the standpoint of human life and welfare, but, in the present state of knowledge and science, is most disgraceful. No undue combination of malevolent circumstances is responsible for it, but simply general carelessness, both personal and public, on the part of those who can have no excuse for it. Within the past twenty-five years approximately 2,000,000 individuals in Philadelphia have been vaccinated under municipal supervision, and, with the exception of a few inoculated after direct exposure to the disease and too late to protect them, no case is known to have occurred in this great number within the minimum time—six years—of safe protection.

To controvert those who assert that this prophylactic measure is of no value, the following statistics are quoted from McFarland, from Welch and Schamberg, and from Harrington: Prior to the adoption, April 1, 1875, of the German law requiring vaccination at birth and at the tenth year, the annual mortality in Prussia, from 1816 to 1870 was from 7.32 to 66 per 100,000 of population; in 1871 it was 243.2, and in 1872 it was 262.67, owing to the introduction of French prisoners. Since then there has been no epidemic, but from 1875 to 1886 the average annual mortality was 1.91 per 100,000 and the lowest 0.36. On the other hand, from 1870 to 1895 over 20,000 died from smallpox in Paris alone, where vaccination is not compulsory.

In the following table, note that vaccination was compulsory in the first five cities and not enforced in the other four:

DEATH-RATE FOR SMALLPOX.

(in 100,000 of population—1875–1889).

Berlin	1.16
Hamburg	0.74
Breslau	1.11
Munich	1.45
Dresden	1.03
Paris	26.24
St. Petersburg	35.82
Vienna	64.90
Prague	147.90

According to Harrington, in the Sheffield epidemic of 1887–88, 1.55 per cent. of vaccinated and 9.7 per cent. of unvaccinated were attacked, the death-rate among the former being 0.7 and among the latter 48 per 1000. Among children under ten the rate of attack was 5 and 101 per 1000 respectively for vaccinated and unvaccinated, and the death-rate was 0.09 and 44 per 1000. From the statistics of this epidemic we have:

RATES OF ATTACK PER 1000 PERSONS.

Persons not vaccinated	94.00
Persons once vaccinated	19.00
Persons twice vaccinated	3.00

DEATH-RATES PER 1000 PERSONS.

Persons not vaccinated	51.00
Persons once vaccinated	1.00
Persons twice vaccinated	0.08

The same authority states that a "successful primary vaccination within three days after exposure to existing cases of smallpox will prevent the development of the disease, and as late as the fifth or sixth day will either prevent or modify an attack." So that epidemics, even when well under way, can be checked by wholesale vaccination.

However, vaccination should be repeated from time to time, especially when there is danger of infection. In Philadelphia, in 1901–04, not one of the 3500 smallpox patients treated at the Municipal Hospital had been suc-

cessfully vaccinated, as evidenced by the scar, within four years of the attack, and this in spite of the fact that about 500,000 persons, or one-third of the city's population, were vaccinated during this epidemic.

From the data of this hospital Welch and Schamberg compiled the following:[1]

	Cases.	Deaths.	Percentage of deaths.
Vaccinated in infancy, good scars . .	2335	152	6.50
Vaccinated in infancy, fair scars . .	1105	135	12.21
Vaccinated in infancy, poor scars . .	1524	345	22.64
Postvaccinal cases	4964	632	12.53
Unvaccinated	3687	1542	41.82
Total	8651	2174	25.13

Again in the same hospital, "during a period of thirty-four years, in which time over 9000 cases of smallpox have been treated, not a physician, nurse, or attendant who had been successfully vaccinated or revaccinated prior to going on duty, contracted the disease." In addition, during more than twenty years many hundreds of medical students have visited this hospital to study infectious diseases, the only one of them to incur smallpox being a student who surreptitiously evaded the requirement of vaccination preliminary to visiting the smallpox wards.

Surely, with modern statistics such as the foregoing at hand, it is not necessary to recall the excessively high mortalities of the eighteenth century prior to Jenner's discovery, amounting to half a million or more annually in Europe, to convince intelligent persons of the great value of this one method of prophylaxis, and yet legal compulsion seems to be necessary to secure its general employment. Otherwise, if the public at large could be trusted properly to protect itself, the recent and startling record of the country already referred to could not have been made.

In advocating the practice of vaccination it must not

[1] Acute Contagious Diseases, page 55.

be implied that one inoculation necessarily protects the individual throughout life. Just as in the case of other infectious maladies, the immunity may gradually be lost in the course of years. One attack of measles, scarlet fever, etc., generally protects against subsequent ones, and yet every one knows of cases of recurrence, and to such a contingency smallpox is no exception.

During the first six months of 1925 there were in Philadelphia 183 cases of the disease with 23 deaths. Of these cases 128 had never been vaccinated and none of the remaining 55 within seven years. One had been vaccinated seven, another eight, and a third ten years previously; the next in order, eighteen and nineteen respectively, while the average time since vaccination for the entire 55 was almost thirty-six years. Forty-nine of them had been inoculated at two years of age or less, 4 at six, 1 at nineteen and 1 at thirty-six, the latter being the one whose protection had been of shortest duration. It is also of interest to note that for the 6 of the vaccinated who died the average time since inoculation was forty-one years, the shortest period being twenty-two years.

Granting that the operative technic was perfect and that there was a "true take" or positive protection with good virus in each of these cases—which is not probable when all is considered—it is not at all surprising that immunity was lost after such intervals, and the record in no wise minimizes the value of the procedure.

Various factors, some still unsettled, must determine the advisability of the use in a given case of one or another of the methods of securing immunity already described; but it must be remembered in regard to actively acquired immunity, that not only is it at times too slow in development to be of value after infection has occurred, but also that "the introduction of toxins or bacterial proteids after the onset of the disease may be not merely useless, but actually harmful by adding to the sum total of toxic material against which the tissues struggle."

Finally, experience will continue to show that whether

one or all of these methods of securing immunity may be employed or whether others by which the body can protect itself may be discovered, sanitation and a condition of perfect health throughout the system are of the utmost importance in helping to ward off attacks or in securing immunity from any of the pathogenic organisms, and in withstanding their ravages should disease be incurred. A sound body is a most vitally active and not simply a passive agent for the prevention of such diseases, and although no previous or present state of good health can insure anyone absolutely against infection, the fact that the body cells and tissues are in good condition and active function gives good promise that they will be more able to defend the body in time of need. It may be true that, in a given case, they will have to adapt and adjust themselves to the presence and influence of entirely new and unaccustomed poisons and that they may even succumb to them, but they will surely make a better fight of it than if they are already weakened by disease or in poor condition because of faulty habits.

CHAPTER V.

THE ATMOSPHERE—AIR.

The composition of the atmosphere surrounding the earth is remarkably uniform. It is practically always the same everywhere, provided no obstacle be interposed to the action of those natural forces by which this uniformity is maintained. This atmosphere is estimated to be about forty miles in depth, and its weight-pressure, of which we have a visible manifestation in the action of the barometer, upon the total surface of the adult human body is equivalent to that of about fourteen tons. Any considerable variation in this pressure may give rise to disturbances of health more or less serious, such as the cardiac derangements and "mountain sickness" experienced by strangers visiting high altitudes and by aviators, or the "caisson disease" of those who work in a compressed atmosphere. In fact, it is not improbable that some of the vague disturbances of comfort to which a large class of persons are subject during changes of the weather will hereafter be found to be due to the marked variations in this pressure at such times.

The average composition of the air in its normal state is about as follows: oxygen, 20.96 per cent. by volume; nitrogen and argon, 79 per cent.; carbon dioxide, 0.04 per cent.; aqueous vapor, varying in amount with the temperature and other conditions; a trace of ammonia, and a variable amount of ozone, organic matter, sodium salts, etc. The variation in the percentage of oxygen may be from 20.87 in towns to 20.98 in pure mountain air or far out at sea; in the percentage of carbon dioxide, from 0.02 to 0.05. So far as we know at present, the nitrogen

variation is almost infinitesimal. The air is a mechanical, not a chemical mixture, and there is always some change taking place in the proportions of the various constituents. However, the mixture is maintained in its wonderful uniformity by the interdependent action of plants and ani-

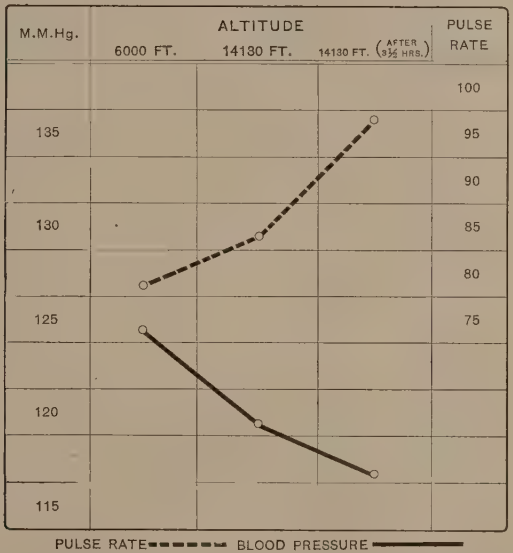


FIG. 16.—Physiological changes due to rapid change in altitude. Average blood-pressure and pulse-rate of 22 young men. Adapted from papers of Drs. Gardner and Hoagland in the Transactions of the American Climatological Association, 1905, xxi, 85.

mals, and by the diffusion of gases, the law of which is that "a gas expands into a space in which there is another gas as freely and as rapidly as if there were a vacuum." Though this agency, like the other, is continually operating, its results are greatly facilitated by adventitious air-currents and by the application of heat. When a gas is

thus diffused, it will not separate again from the others under ordinary circumstances.

Oxygen is the most important of the above constituents. It supports all animal life; oxidizes, destroys, and renders harmless organic impurities, and by oxygenating the blood and oxidizing the food for our tissues gives heat and energy, the vital source of all our thoughts and actions. The supply to the atmosphere is constantly maintained by the higher plant-life, which decomposes carbon dioxide and gives off oxygen to the air. In man the greatest limit of life without oxygen or air is about four minutes. A decrease in the proportion of oxygen in the air does not usually manifest itself by untoward symptoms in the human body until there is less than 13 per cent. by volume; then as it falls lower and lower the respirations become slower, deeper, and more difficult, less oxygen is absorbed by the blood, and there follow dyspnea, asphyxia, and death. This may occur within a short time when the percentage goes below 8 per cent., and fatal asphyxia supervenes very rapidly when there is as little as 3 per cent. of oxygen.

Some very interesting investigations made by the Medical Research Board of the Air Service of the U. S. Army in 1918 show that "in normal men characteristic alterations of function begin even with a slight lowering of the oxygen tension," and that "for all persons there are limits beyond which the body cannot compensate. In this respect there are the widest individual variations, forming a scale from the man with a weak heart, who can withstand scarcely any reduction of oxygen, up to the man whose respiration and circulation are of such adaptability and power that he can go to 25,000 feet and yet for a time be virtually normal. The strain imposed by altitude is closely similar to that induced by extreme physical exertion. In both conditions oxygen deficiency occurs, but at altitudes and in an aëroplane the effects are the more subtle and dangerous because of the lack of stimulation to breathing and other

functions that the increased carbon dioxide production affords during muscular exertion."[1] The same investigations show that while the rate of heart-beat has been found to accelerate in a few men at 17.5 per cent. of oxygen, corresponding to an altitude of 5000 feet, only 13 per cent. of those examined reacted in this way until the oxygen was reduced to less than 15 per cent., and that "the pulse-pressure remains fairly constant in most men until the oxygen has fallen to between 12 and 9 per cent. (from 14,500 to 22,000 feet), after which it increases in amount during the further reduction in oxygen."

The main function of the nitrogen of the atmosphere seems to be to act as a diluent and to prevent the too energetic action of the oxygen. We know now, however, that at least one family of plants—the leguminosæ—is able, by the aid of certain bacteria, to take nitrogen almost directly from the air and to store it in the form of proteids for future use as a food for animals. The ammonia ever present in the air is also a source of nitrogen food for some plants.

The gaseous element *argon,* discovered in 1894 by Lord Rayleigh and Prof. Ramsay, comprises about 1 per cent. of what was previously considered atmospheric nitrogen. Thus far little is known concerning it except that its atomic weight is probably somewhat less than 40, its density about 20, and that it is very inert, though Berthelot has succeeded in making it combine with nascent vapors of benzene under the influence of an electrical discharge. That it is a constant component of the atmosphere for some definite purpose is more than probable, but what this purpose may be is as yet unknown.

The carbon dioxide[2] present in the atmosphere is of no direct use to animals, but is essential to the support of vegetable life, furnishing part of the carbon necessary for

[1] Medical Studies in Aviation, Jour. Am. Med. Assn., October 26, 1918, No. 17, vol. lxxi.

[2] Carbon dioxide = carbonic acid gas = carbonic anhydride = CO_2. Carbon monoxide = carbonous oxide = CO.

the formation of the carbohydrates and proteids, which are, next to water, the main constituents of plants. The proportion of carbon dioxide in the out-door air varies somewhat from time to time, owing to the changing conditions. It is washed out of the air by rain, and there is therefore less after a heavy storm; plants absorb it by day, and some give off a slight quantity by night; the strata of the atmosphere near the ground receive an excess of it from the soil-air; it is a constant product of combustion and of the decomposition of organic matter by saprophytic bacteria, etc. Though heavier than air, it is comparatively evenly distributed through the atmosphere by the force of diffusion.

The normal proportion in the atmosphere varies from 0.02 per cent. to 0.05 per cent., but we may take the average to be about 0.04 per cent. Should, however, any important tests of the amount in-doors be required, the percentage in the out-door air at that particular time and place should for the sake of accuracy also be determined. Within the limits just given, the carbon dioxide cannot be considered as an impurity of the atmosphere, for it is ever present in the air, and is as necessary to plant-life as oxygen is to animals. It is derived from the combustion of carbonaceous materials, from the exhalations and excretions of animals and men, and, as was indicated, in large measure by the action of the saprophytic bacteria and also of the budding fungi upon organic matter. Moreover, any excess above the normal percentage as given is to be regarded not so much an impurity of the atmosphere as an indication that certain processes are at work, which by their other products or in their results may make the air impure and unsafe for human use.

The amount of aqueous vapor in the atmosphere varies from time to time because the factors governing it—condensation and evaporation—are continuously in action, these depending, of course, mainly upon the continual variations in temperature. There is probably never a perfectly dry air unless it is made so artificially, and

precipitation occurs the moment complete saturation is reached. The usual range of relative humidity is probably from 30 to 100 per cent., this being equivalent, according to the temperature, to a water-content of from 1 to 12 or 14 grains to the cubic foot of air. The most satisfactory proportion for health has not been experimentally determined, but is generally considered to be from 40 to 70 per cent. when the temperature is moderate.[1]

In the outdoor air there is at least a trace of ammonia either free or combined, a small amount of the salts of sodium (especially near the sea) and of other metals, and a trace of organic matter. This last is part of the animal and vegetable débris of the earth; when above a trace, it is to be treated as an impurity, as should any excess of ammonia.

Minute particles of innumerable substances are being constantly thrown off into the atmosphere, and it is only the unceasing action of nature's purifying powers that keeps the proportion within the limits of safety to the human race. Solid particles, lifted up by the winds, fall to the earth again, or, if organic, are partially oxidized and decomposed by the oxygen and ozone. The gases are diluted and diffused so as to be no longer harmful, or are decomposed, or are washed back to the earth by rain or snow. The great volume of carbon dioxide is kept within bounds by the action of the vegetable world. The natural purifiers of the atmosphere, therefore, are the force of gravity, diffusion, dilution by the air itself, winds, oxidation, rain, and the action of plant-life; and so exactly are these adjusted to their work that never, when they have fair opportunity to act, does the composition of the air vary much from the normal for any great length of time.

The impurities in the atmosphere that are especially

[1] When the temperature is upward of 80° F. a humidity of but little more than 70 per cent. may be very uncomfortable and depressing if the air is still and evaporation from the body surface thus impeded. A breeze makes such humidity or even a higher one less noticeable.

likely to have a deleterious influence upon health may be classed as follows: (1) Suspended matters. (2) Gaseous and semigaseous substances, including: (3) Those especially due to combustion and decomposition processes, and which are particularly likely to contaminate the air of dwellings or inhabited apartments.

The most important suspended matters are sand, dust, soot, pollen of various plants, microörganisms of all kinds, particles of epithelia and other excreta thrown off from animal bodies, and finely divided substances characteristic of certain trades or industries. These may do harm by clogging the air-vesicles of the lungs and thus obstructing respiration, though it is doubtful whether their action is ever only so mild or simple; by their irritant action upon the respiratory passages;[1] by being in themselves poisonous or hostile to the system, or, as in the case of microörganisms, by the influence they have in the causation of disease. Disease germs may lodge in the respiratory passages and do harm, or may be swallowed and so cause maladies, such as typhoid fever or cholera, which primarily affect the digestive tract.

It is, however, questionable whether pathogenic organisms, especially the bacteria, are commonly to be found dissociated from other substances floating in the air. Experiments by Cornet, Tyndall and others seem to show that such microbes are more apt to be adherent to dust particles, particularly those of organic nature, and it is probable that free bacteria in the out-door atmosphere could not long maintain their vitality deprived of nutriment and exposed to the action of light and oxygen. Besides, they are so quickly dispersed and reduced in numbers in any reasonable volume of unconfined air that the occasions must be rare indeed when they could thus cause

[1] The pollen from certain varieties or species of plants is thought by many to have a specific influence in the causation of hay fever and similar ills, and there seems to be no doubt that it is frequently an aggravating and predisposing factor in the development or course of such disturbances.

disease. In-doors, especially where ventilation is neglected, the case is different, and there is no doubt that the air may thus occasionally become the carrier of dangerous pathogens.

We must also make a distinction as to whether the other solid impurities are found in the out-door air or in enclosed spaces; and if in the latter, whether in healthful dwellings, in sick-rooms and hospitals, or in workshops and factories. Out-of-doors, dust, sand, soot, pollen, waste dirt from dwellings, street refuse, and the remains of plant and animal life will predominate; in-doors the particles will be more limited in variety, but not in importance. Among them will be epithelial and other cells, possibly pus-corpuscles, hair, bits of clothing, food, etc. One may also find arsenical or other poisonous dust from wall-paper or paint. In sick-rooms and hospitals there will probably be pus-cells, mycelia, bacteria, etc. Mills, factories, and mines have their special atmospheres laden with particles peculiar to the occupation, which in many cases have a marked influence for harm on the health of the workers.

The gaseous and semigaseous impurities of most importance are not so much those resulting from human respiration and cutaneous exhalations, but rather the products of combustion, peculiar gases in sewer-air or soil-air, organic emanations and vapors from decomposing animal and vegetable matter, and the volatile substances that characterize the various atmospheres in and about gas-works, factories, and other places of industry. Chemically, they may be classified as the compounds of carbon and of sulphur with oxygen and hydrogen, ammonia compounds, volatilized minerals and mineral acids, and many gaseous and semigaseous matters of organic nature but indeterminate composition.

Inasmuch as certain of these impurities, viz., human exhalations, combustion-products, and not infrequently the so-called sewer-gas, are particularly liable to be found together as contaminants of the atmosphere of inhabited

rooms and dwellings, it will be advisable to consider them in a class by themselves, and to study their effect upon health both collectively and singly.

The volatile excreta from the body are carbon dioxide, aqueous vapor, and a considerable amount of nitrogenous organic matter, to which the term "crowd-poison" is sometimes given. As products of combustion from the ordinary lighting and heating apparatus of dwellings we may have carbon dioxide, carbon monoxide, sulphur dioxide, ammonia (with possibly its sulphide), and aqueous vapor. Of sewer-gas and soil-air we shall speak later.

Carbon dioxide, contrary to the general opinion, cannot be said to be directly harmful to health in the proportions in which it is likely to be found in any dwelling or inhabited apartment. Although present to the extent of not more than 0.05 per cent. in normal out-door air, numerous experiments indicate that both men and animals may inhale much larger proportions than this without apparent harm provided the percentage of oxygen in the air be maintained at or above the normal; an increase of the carbon dioxide from other sources than respiration and combustion seems to have no appreciable effect upon health until it amounts to at least 1 or 2 per cent., and some men work daily in atmospheres containing almost this amount as a result of their peculiar occupations. Dyspnea does not begin to occur, and then only in some, until the percentage goes above 3 or 4. In quantities above these figures there is much difference of opinion as to the effect of the gas upon the human economy, and the writer is not aware that it has ever been determined just what percentage is fatal. Parkes states the lethal proportion to be from 5 to 10 per cent.; while another authority states that animals may be kept for a long time in an atmosphere in which there is a high percentage of carbon dioxide provided the percentage of oxygen be increased at the same time. Hime says that "it may be assumed that 10 or 20 per cent. is a dangerous

amount;"[1] but Wilson[2] shows that air having from 25 to 30 per cent. may be inhaled with impunity. It is to be understood that the above percentages are all *by volume.*

According to his weight, an adult man at rest absorbs from 15 to 18 cubic feet of oxygen and exhales from 12 to 14 cubic feet of carbon dioxide in twenty-four hours. Reichert[3] says: "The amount of O varies from 600 to 1200 grammes (15 to 30 cubic feet) per diem, and that of CO_2 from 700 to 1400 grammes (12.5 to 25 cubic feet)—approximate averages being about 750 grammes of O and 875 grammes of CO_2." According to Ott,[4] "The amount of water thrown off daily is about a pound; of oxygen taken in, about a pound and one-half; and of carbonic acid thrown off, a little more than a pound and one-half." The minimum excretion per hour may therefore fairly be taken to be about 0.7 cubic foot of carbon dioxide for adult men and 0.6 cubic foot for women or for each person of a mixed assemblage. Now, granting the presence of a single adult occupant, it is evident that it would require many hours before even a small room of, say, 1000 cubic feet capacity would lose sufficient oxygen or gain sufficient carbon dioxide to produce the slightest apparent harmful results, even though ingress of fresh air were prevented; and yet experience tells us that the atmosphere of such a room will become exceedingly foul and actually detrimental to health long before the lapse of time necessary to exhale sufficient carbon dioxide to induce serious effects. Moreover, carbon dioxide is odorless, while the air of inhabited, unventilated rooms is characterized by a decidedly offensive smell that remains for some time even after adequate ventilation has been secured and when chemical tests show the percentage of carbon dioxide to have been reduced to nearly the

[1] Stevenson and Murphy, vol. i, p. 945.
[2] American Journal of Pharmacy, 1893, p. 561.
[3] American Text-book of Physiology, p. 536.
[4] Text-book of Physiology, 4th ed., p. 392.

normal. "The chemical analyses of the air of overcrowded rooms, and the experiments upon animals made by many investigators, indicate that the evil effects observed are probably not due to the comparatively small proportions of carbonic acid usually found under such circumstances. . . . The proportion of increase of CO_2 and of diminution of oxygen which has been found to exist in badly ventilated churches, schools, theatres, etc., is not sufficiently great to account satisfactorily for the great discomfort which such conditions produce in many persons, and there is no evidence that such an amount of change in the normal proportion of these gases has any influence upon the increase of disease and death-rates which statistical evidence has shown to exist among persons living in crowded and unventilated rooms."[1] Therefore it must be something other than carbon dioxide that vitiates the air of dwellings and necessitates the provision of some system of ventilation. However, with our present knowledge we cannot say that a diminution of oxygen and an increase of carbon dioxide in the atmosphere which one breathes habitually do not tend to lower the general tone and perhaps the bactericidal powers of the body and thus to render it more susceptible to deleterious influences, and, since there is some evidence that as the carbon dioxide in the atmosphere increases there is a lessening of the amount of this gas excreted from the body, it will on general principles always be wiser to use every reasonable means to maintain the normal proportion of the various gases in the atmosphere. Moreover, the fact that tuberculous patients usually improve if they live continuously out of doors would seem to indicate that the full quota of oxygen in the air is essential to the best interests of health, and also that in-door air, though apparently but slightly impure, favors the development and progress of this disease. There are, however, other explanations

[1] The Composition of Expired Air and Its Effect upon Animal Life, Mitchell, Billings, and Bergey, No. 989, vol. xxix, Smithsonian Contributions to Knowledge.

for this improvement, such as, for instance, the sunlight or ultra-violet rays, and one cannot at present state, which, if any, are the most important factors in this method of treatment.

Aqueous vapor is another of the substances excreted continually from both the lungs and the skin; but it is obvious that in itself it cannot be directly harmful to the system, for we find it ever present in all natural atmospheres, and are continually replacing by imbibition its loss from our bodies. The quantity daily thrown off from the lungs and skin will depend on the temperature and humidity of the atmosphere, the quantity of air inspired and water imbibed, and many other factors; but under ordinary conditions the average excretion will be from 100 to 1700 grammes (about 3.5 to 60 fluidounces), though increased exertion might cause even the latter amount to be greatly exceeded. This large quantity of moisture, tending to saturate an atmosphere already humid, and thus preventing evaporation from the skin, indirectly and reflexly checks the loss of heat from the body and the excretion of waste matters by the sweat-glands so that the retention of excessive heat and of such wastes in the system probably helps to produce the depression, headache, and other symptoms experienced by those in foul and humid air. It has been noticed that the symptoms due to foul air are more readily manifested when the temperature of the atmosphere is much below or much above the usual room-temperature of 65° to 70° F. At low temperatures the air is readily saturated, and beside, the excreting action of the skin is much lessened by the cold; at high temperatures the humidity is often already near the saturation-point, while the external heat tends to increase the quantity of water given off by the lungs and skin. "At high temperatures the respiratory centers are affected where evaporation from the skin and mucous surfaces is checked by the air being saturated with moisture—at low temperatures the consumption of oxygen

increases and the demand for it becomes more urgent."[1] At 70° F. the aqueous exhalation from an adult body would in an hour or less completely saturate from 350 to 600 cubic feet of air which already had the not unusual relative humidity of 75 per cent., while at 80° F. an equal or even greater volume of air would doubtless more quickly gain its maximum of moisture from the increase of perspiration due to the extra heat. Moreover, as evaporation of the perspiration is one of the most important means for maintaining the balance between the heat-production and heat-dissipation of the body, interference with this process naturally tends to raise the body-temperature rapidly and to produce the consequent effects upon the nervous mechanism. A stagnant atmosphere, likewise, is more depressing than one in motion, even though temperature and humidity be unaltered, since the movement of the air favors evaporation and probably acts also as a gentle stimulant to the skin.

Crowd-poison.—The third contaminant given to air from human bodies is an indefinite volume of offensive organic matter, and for a time this was looked upon as by far the most harmful part of animal exhalations. But recently experiments by various investigators have seemed to indicate that this organic effluvium is not so dangerous as it has higherto been considered, and that most of the symptoms due to air vitiated by respiration are to be attributed to the conditions already mentioned, viz., increase of heat and moisture, together with lack of sufficient air movement. It is also doubtful whether much, if any, of this organic matter comes from the *lungs* of healthy persons.[2] "In ordinary quiet respiration no bacteria, epithelial scales, or particles of dead

[1] Mitchell, Billings, and Bergey, loc. cit.

[2] Flügge, Hill, and others have found that the evil of close atmospheres is largely a result of elevated temperature, humidity, and absence of air currents. Tests were made on men who sat in impure air, but breathed pure air through tubes, and they presented all the symptoms usually resulting from bad ventilation. Report on Human Vitality, Fisher, p. 85.

tissue are contained in the expired air. . . . The cause of unpleasant, musty odors in rooms may in part be due to volatile products of decomposition from decayed teeth, foul mouths, or disorders of the digestive apparatus, and in part to volatile fatty acids given off with or produced from the excretions of the skin, and from clothing soiled with such excretions."[1] However, whatever may be the exact source of this contamination, we know this concerning it—that it is decidedly offensive to the sense of smell, that it is organic and nitrogenous, yielding ammonia, darkening sulphuric acid, decolorizing potassium permanganate, and rendering obnoxious pure water through which the vitiated air has been drawn. While it seemed to such careful observers as Brown-Séquard, d'Arsonval, Merkel, and others to be directly poisonous to lower animals, modern scientific evidence of this effect is lacking. In general, it is given off proportionately with the carbon dioxide from the body, though this rule is not infallible; it is apt to be unevenly distributed throughout the atmosphere of the apartment, and is probably therefore not truly gaseous, but more like an impalpable dust; it oxidizes but slowly, being evident for some time after fresh air has been admitted and the carbon dioxide has been reduced almost to the normal, and, while neither condensed nor dissolved in the aqueous vapor from the body, it is especially attracted and retained by hygroscopic substances such as wool, paper, feathers, etc. Its smell is generally perceptible when the *respiratory* carbon dioxide reaches 0.03 or 0.04 per cent.—sometimes before this point is reached, especially in sick-rooms or hospital wards —and is decidedly offensive when the total carbon dioxide approaches 0.1 per cent., provided the excess above the out-door normal is all from the human body.

The most important of the impurities resulting from the combustion of coal, the principal fuel substance used in towns and cities, are soot and tarry matters (to the ex-

[1] Mitchell, Billings, and Bergey, loc. cit.

tent of about 1 per cent. of the coal consumed), carbon monoxide and dioxide, aqueous vapor, and more or less ammonium sulphide, carbon disulphide, hydrogen sulphide, sulphur, sulphur dioxide, and sulphuric acid. The relative amounts of the oxides of carbon—as well as of the other gases—will depend upon the perfection of combustion; "but it has been calculated that for every ton of coal burnt in London something like three tons of carbon dioxide are produced," and as the coal consumption of that city is over 30,000 tons per diem, we can readily see that its atmosphere must receive the enormous daily contamination of about 300 tons of soot and 90,000 tons of carbonic acid. No wonder they have an *occasional* fog there!

The combustion-products of wood are in the main carbon monoxide and dioxide and water, while those of coke and of gas are practically the same as those of coal. From the heating apparatus, if properly constructed and arranged, these products pass almost directly to the exterior of dwellings and are rapidly dissipated in spite of their excessive volume, for "diffusion and the ever-moving air rapidly purify the atmosphere from carbon dioxide," and in fact from the other combustion-products also, with the exception of the soot and tarry products.

Should, however, combustion be incomplete, or should the stoves or other heating apparatus be imperfect, the gases may seriously or even dangerously contaminate the house-air, the deadly carbon monoxide being particularly liable to leak not only through the crevices, but actually through the heated cast-iron plates, etc., of stoves and furnaces. Theoretically, a pound of coal requires 160 cubic feet of air for its perfect combustion, but actually from one-half to as much more must be supplied to the ordinary heating apparatus to secure complete oxidation of the fuel.

Practically all the devices for artificial illumination, with the exception of the incandescent electric light, give off directly to the surrounding air combustion-products

which are much the same as those from coal, and this contamination is consequently a positive factor in the vitiation of in-door air. "Every cubic foot of coal-gas yields, on combustion, roughly, half its own volume, or 0.52 cubic foot, of carbon dioxide, and 1.34 cubic foot of water vapor," besides some little carbon monoxide when ordinary burners are used. "Speaking generally, it may be said that each cubic foot of gas burnt per hour from the ordinary burners vitiates as much air as would be rendered impure by the respiration of an individual; it at the same time will raise the temperature of 31,290 cubic feet of air 1 degree F., and yields 217 calories (a kilogramme of water heated 1 degree C.) or 860 British heat-units (a pound of water heated 1 degree F.)."[1] But inasmuch as the products of combustion are superheated, they rise at once to the top of the room and usually, for the most part, quickly escape to the outer air through the combined influence of negative gravity and diffusion; so that comparatively little air is needed to dilute the small proportion of such products that eventually cool and fall to the breathing-level.

The accompanying table[2] shows the influence of various lighting agents with respect to the condition of the room-air.

From this table it will be learned that the incandescent electric light is the most satisfactory from a hygienic point of view, and there is no doubt that its very general introduction has done much toward obviating a constant source of vitiation, especially in rooms which require much artificial light, and are at the same time difficult to ventilate. It is said that in a bank in London, in which several hundred persons are employed, the absences on account of illness have been so far reduced, apparently by the introduction of the incandescent electric light alone, that the extra labor gained has more than compensated for the increased cost of lighting. The general

[1] Notter and Firth, Treatise on Hygiene, p. 140.
[2] Ibid., p. 141.

use of tungsten instead of carbon filaments for incandescent electric lamps is a recent improvement that provides a whiter, steadier and more brilliant light, and at a reduced cost for current. The electric arc light is said to form nitric acid; but even so, its effects are not so harmful as are those of the products of combustion of the ordinary candle, lamp, or gas-jet.

	Quantity consumed.	Candle-power.	Oxygen removed.	Carbon dioxide produced.	Moisture produced.	Heat calories produced.	Vitiation equal to adults.
			Cu. ft.	Cu. ft.	Cu. ft.		
Tallow candles	2200 grains	16	10.7	7.3	8.2	1400	12.0
Sperm candles	1740 "	16	9.6	6.5	6.5	1137	11.0
Paraffin-oil lamp	992 "	16	6.2	4.5	3.5	1030	7.5
Kerosene-oil lamp	909 "	16	5.9	4.1	3.3	1030	7.0
Coal-gas No. 5 batwing burner	5.5 cu. ft.	16	6.5	2.8	7.3	1194	5.0
Coal-gas, Argand burner	4.8 "	16	5.8	2.6	6.4	1240	4.3
Coal-gas, regeneration (Siemens) burner	3.2 "	32	3.6	1.7	4.2	760	2.8
Coal-gas (Welsbach incandescent)	3.5 "	50	4.1	1.8	4.7	763	3.0
Electric incandescent light	0.3 lb. coal	16	0.0	0.0	0.0	37	0.0

Next to the incandescent electric light in importance are the Welsbach and Siemens gas-lights; but of these the latter has not the illuminating power, nor is it so well adapted to house use as is the former. The Welsbach light makes use of the Bunsen flame (in which, by the way, the carbon of the gaseous fuel is completely oxidized and converted into carbon dioxide) to render incandescent a non-combustible mantle or network, composed of vegetable fiber saturated with the oxides of certain metals which have the property of becoming

intensely luminous when sufficiently heated. It gives a white light of great illuminating and considerable actinic power, and of practically unvarying intensity. In fact, this quality of steadiness, in which it even surpasses the earlier types of incandescent electric light, is by no means the least of its hygienic advantages, since such steadiness is an important factor in the conservation of the eyesight.

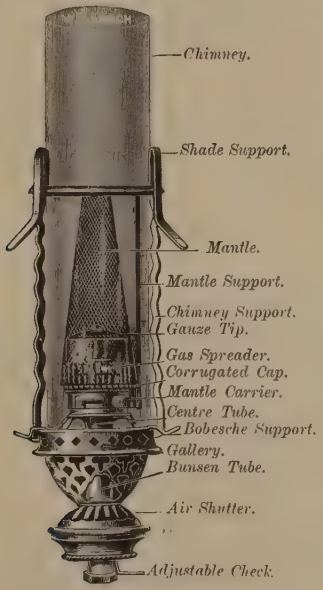


FIG. 17.—Welsbach light.

Recently hydrocarbon (kerosene and gasoline) lamps, making use of an incandescent mantle similar to the Welsbach, have been placed on the market, and are said to be safe and free from odor or danger of explosion. If these claims can be sustained, such lamps are of value,

since they furnish a powerful and steady incandescent light at very low cost.

A comparatively new illuminant, not mentioned in the foregoing table, is acetylene gas. This gives a very white and powerfully actinic light, and, on account of ease of production and the small amount needed for ordinary lighting, is cheap and does not greatly vitiate the atmosphere. But a mixture of the unburned acetylene with air in proportions of from 4 to 25 per cent. is highly explosive, and consequently the gas is not yet much used for interior lighting.

Sewer-gas and Soil-air.—What is commonly called sewer-gas is a mixture of a number of gases, such as carbon dioxide, carburetted hydrogen, ammonium and hydrogen sulphide, nitrogen, etc., together with a considerable amount of fetid organic matters, the volatile or semi-volatile products of animal and vegetable decomposition, all varying according to the condition of the sewer, the kind of matter received therein, the amount of surface-water, etc. The air from a closed cesspool may be extremely foul and poisonous, so much so that the emanations have not infrequently caused death in those who inhaled them in full concentration; on the other hand, the atmosphere of a properly constructed and well-flushed sewer may be almost as pure as that above the surface of the ground. Fresh sewage is not so likely to contaminate the air above it with microbes as that in which decomposition has begun, since Frankland has shown that solid or liquid particles are not liable to be scattered into the air by any disturbance to which the sewage may be subjected until gases of decomposition are produced. According to some writers, the bursting of bubbles of gas on the surface may discharge the bacteria into the sewer-air. It has also been shown that "bacteria can undoubtedly grow up the sides or walls of damp, nutrient sewers, and if these latter become at all dry, air currents readily detach and disperse them." It is, however, questionable whether many disease germs can

withstand the natural antagonism of the saprophytic bacteria that predominate in sewage and on sewer walls.

Another class of impurities that may at times be found in the air of dwellings comprises those coming from the soil and soil-air. The *soil,* in hygiene, refers to all that

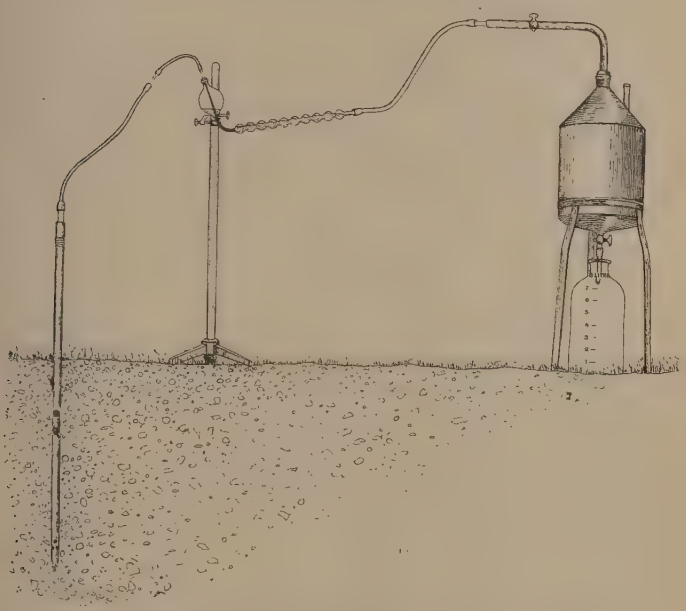


FIG. 18.—Apparatus for determination of carbon dioxide in soil-air. (Harrington.)

portion of the earth's crust that can in any way affect the health. All soils contain more or less air—soft sandstones from 20 to 40 per cent., loose sand from 40 to 50 per cent., and loose soils often very much more.

As the soil is the recipient of most of the solid and

liquid waste of all animal and vegetable life, and as the myriads of saprophytic bacteria that inhabit its upper strata are constantly working to convert this dead organic matter into simpler compounds suited to the nourishment of plant-life, the soil-air, taking the atmosphere above as a standard, will usually be far from pure.[1] It is rich in carbon dioxide and in organic vapors and gases, while the proportion of oxygen is probably always less than that of the air above ground. Moreover, the carbon dioxide increases and the oxygen decreases the deeper below the surface the sample is taken. As much of the carbon dioxide is evidently derived from organic pollutions, it might be supposed that this gas could be taken as an index of the degree of the latter, and so it might if other conditions, such as permeability of soil, rate of circulation, etc., were always the same. But they are not, and the composition of the soil-air is practically not the same at any two places, nor for the same place at different times. The underground-air is constantly in circulation, even to a considerable depth; but there is a hindrance to its free movement and diffusibility, and this, together with the great variation in the distribution of oxidizable and other contaminating matters, causes the variations in its composition. The carbon dioxide therefore cannot be taken as an index of the relative purity.

The forces that maintain the circulation of the ground-air are the wind, the daily change of surface temperature, the fall of rain, and especially in winter the local and artificial conditions of civilization. A very slight wind will drive air through the soil for long distances, the rise and fall of the ground-water has its obvious effect, and the movement due even to slight changes of temperature is likely to be quite extensive and positive.

Owing to evaporation from the ground-water, the soil-

[1] Too much importance cannot be attributed to this saprophytic action in the upper soil, for it is one of nature's wonderful methods of securing and conserving not only the purity of our environment, but also the perpetuation of organic life.

air is always quite humid, and, according to some writers, may also be laden with bacteria and other very light substances lifted up by the ascensional power of evaporation. This possibility, however, is a doubtful one, and is not credited by other authorities.

As sewage, house-wastes, and dirt of all kinds are particularly liable to contaminate the soil about any inhabited dwelling, the air of that soil will more than likely be very impure, and care must be taken that it is not drawn into the house. This is especially apt to happen in cold weather, when house-fires are lighted and the in-door air is thus made warmer than that without, the tendency then being for the soil-air to pass, if possible, through the cellar walls and floors. These should be made as nearly air-tight as possible, and special attention should be given to the space underneath and about the furnaces or basement heating apparatus. As an instance of the importance of these precautions, Hime[1] gives an account of the death of four persons. Enough illuminating- (coal-) gas was drawn from a broken pipe fifteen feet distant from the foundation walls of the dwelling to cause the fatality, although there were only eight or ten inches of tramped earth above the pipe and the only aspirating force was the difference of temperature within and without the house. A number of explosions have occurred, due to a similar leakage of gas from street mains through basement walls or into drains and sewers, since the admixture of illuminating-gas with air forms a most powerful and dangerous explosive.

There is no direct evidence that the emanations from piggeries, bone-yards, soap-factories, garbage-incinerators, etc., are actually harmful to health; but they may be very decided nuisances to those living near by, and may also foster the excessive multiplication of flies, rats, etc., therefore, all such places should be strictly controlled by the proper sanitary authorities.

[1] Stevenson and Murphy, Treatise on Hygiene, vol. i, p. 949.

The atmosphere of mines and other excavations is subject to contamination by the excess of carbon dioxide in the soil-air, by gases from blasting agents and from fissures in rock, and by the products of respiration from men and animals working in the mines, etc. The air in deep cellars or basements, or in the holds of ships is also likely to be foul, owing to the difficulty of changing it sufficiently often, and frequently also to the insanitary character of stored contents or cargoes. In such situations proper ventilation should be secured by all means available, and special care taken that the impure air does not affect the laborers in the one case or the passengers and crew in the other.

DISEASES CAUSED BY IMPURE AIR.

As a rule, the human system has the power of accommodating itself, through habit, to withstand influences which, in one unaccustomed to them, would soon produce serious results. But in spite of this, if the body be exposed for any considerable length of time to conditions of impurity or deterioration in its supply of air, water, or food, such conditions will always tend to undermine health and increase the susceptibility to disease, even though they cause no more serious results. "Statistical inquiries on mortality prove beyond a doubt that of the causes of death which are usually in action, impurity of the air is most important. No one who has paid any attention to the condition of health and the recovery from disease of those persons who fall under his observation, can doubt that impurity of the air marvellously affects the first, and influences and sometimes even regulates the second. . . . The air may affect health by variations in the amount or conditions of its normal constituents, by differences in physical properties, or by the presence of impurities. While the immense effect of impure air cannot be for a moment doubted, it is not always easy to assign to each impurity its definite action.

The evidences of injury to health from impure air are found in a larger proportion of ill health—*i. e.*, of days lost from sickness in the year—than under other circumstances; an increase in the severity of many diseases, which, though not caused, are influenced by impure air, and a higher rate of mortality, especially among children, whose delicate frames always give us the best test of food and air."[1] These facts are now so well recognized that an abundant supply of fresh, clean air is regarded as essential in the treatment of many diseases, and the practise of living as much as possible, and even sleeping, out-of-doors is widely advocated.

The definite diseases caused by the solid impurities in the atmosphere are almost all such as affect the respiratory passages and organs, with the possible exception of those engendered by specific bacteria and other microbes. Much therefore depends upon the physical character of the solid impurities. Soft particles and those with edges smooth and rounded, like soot and coal-dust, may apparently do nothing more than coat or clog the air-vesicles and finer bronchial tubes, and in this way diminish the area of lung tissue exposed to the inspired air, although it is questionable whether any foreign matter in the lungs does not cause more or less irritation. With most of us, however, such impurities are of little account if care be taken to develop the full respiratory capacity of the chest; but where the air is heavily charged with such dust it has a positive effect upon health and duration of life. In 1862 Sir John Simon stated that with one exception "the 300,000 (coal) miners of England and Wales break down as a class prematurely from bronchitis and pneumonia, caused by the atmosphere in which they live. The exception is important. The colliers of Durham and Northumberland, where the mines are well ventilated, do not appear to suffer from an excess of pulmonary diseases, or do so in a slight degree only." Happily, since this was

[1] Stevenson and Murphy, vol. i. pp. 121 and 122.

written satisfactory ventilation systems have been placed in most of the collieries of England, and the condition of the laborers correspondingly improved; but coal-miners are still, as a class, particularly liable to bronchitis, pneumonia, asthma, emphysema, and fibrosis (fibroid phthisis), though they seem to be but slightly subject to primary tuberculosis of the lungs or other organs.

On the other hand, if the particles of dust in the air are hard, angular, and sharp, the lung tissues are readily lacerated, inflammatory processes are quickly set up, and the opportunity for the inoculation of tubercle bacilli and other disease germs is very great. The mortality from tubercular phthisis among metal-miners, needle-cutters, steel-grinders and tool-grinders, etc., is remarkable, and they are also especially subject to asthma and emphysema. Among Cornish tin-miners, 68 per cent. of all sick are consumptive; of needle-makers, over 60 per cent.; of flint-cutters, glass-cutters and -polishers, and of grindstone-makers, from 80 to 90 per cent., etc. It is said that a mixture of mineral and metallic dust seems to be more harmful than metallic dust alone, perhaps because of the greater clogging of the air-vesicles by the mineral matter.

Likewise, with other occupations where there is much irritative dust floating in the air, the effect upon the health of the worker is marked, and we find lung troubles prevalent and many suffering and dying from phthisis, as, for instance, among cotton-spinners, flax-dressers, hemp-dressers, pottery-makers, etc. Defective ventilation, accumulations of noxious gases, improper habits, insufficient disinfection of sputa, and often the excessive humidity of the air necessary in some of these pursuits, have doubtless something to do with the high sick-rates and death-rates; but withal, the marked effect of the solid atmospheric impurities cannot be denied.

Again, workers in poisonous metals, compounds, or gases, such as paint-makers and painters, type-setters, gilders (using mercury), brass-founders, coppersmiths, etc., are subject to the influence of the respective poisons

and the symptoms produced by them, with a correspondingly increased mortality.

Among the diseases that may be caused by the inhalation or swallowing of specific microörganisms floating in the atmosphere are erysipelas, measles, scarlet fever, diphtheria, whooping-cough, infectious pneumonia, phthisis and other forms of tuberculosis, and epidemic influenza; and although the germs of cholera and typhoid fever are usually carried by the drinking-water or food, they doubtless do sometimes find their way into the system from a contaminated atmosphere.[1] As stated in a preceding chapter, however, most cases of infectious disease are more apt to be transmitted by "droplet infection" than by free germs floating in the air.

Only recently has the importance of droplet infection been sufficiently appreciated. By this term is meant the transmission of disease by the germ-carrying spray or moisture discharged from the mouths and respiratory apparatus of sick persons or disease "carriers" into the surrounding atmosphere by coughing, sneezing, cheering or forcible speaking. It is more than probable that a very large, if not the greater, part of the infection of the disastrous and widespread influenzal epidemic in the autumn of 1918 was due to this mode of transmission.

Lastly, the spores of certain fungi which have been found in the air of hospitals and elsewhere are known to cause certain skin diseases, such as tinea and favus; and it is almost as certain that the irritating or poisonous pollen of certain grasses and other plants have much to do with the causation or aggravation of such maladies as hay-fever or rose-cold.

From what has been said, it will be surmised that it is scarcely possible at present to specify the exact effect

[1] The report of the commission appointed to inquire into the prevalence and causes of typhoid fever in the late Spanish-American War shows that in some cases infection was probably due to the dust in the atmosphere which had been raised by many passing feet from the roads over which leaking sewage wagons had been hauled.

upon the health of each of the impurities and influences communicated to the air by the human body, and that the symptoms observed to be due to air thus vitiated are very probably an evidence and result of the combined action of these factors rather than of any one of them singly. However, the writer feels that the oppression so commonly experienced in an unventilated room is most often fairly attributable to the increase in the temperature and humidity and to air-stagnation or lack of sufficient movement; that the headache, disturbed nutrition, and

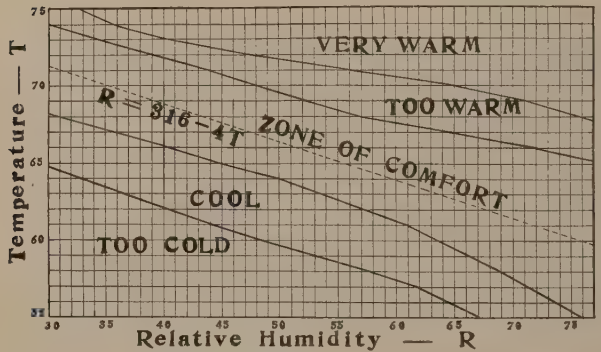


FIG. 19.—Chart showing the relation of the temperature and relative humidity of the atmosphere to comfort.

febrile condition, lasting for hours and sometimes days after exposure to air thus vitiated, are probably due to the same factors, and possibly also, in part, to the suppression of cutaneous excretion dependent upon the high content of moisture in the air; and that the respiratory carbon dioxide by itself can but rarely have much influence upon comfort or health.

If the respiratory and cutaneous vitiation be sufficient to produce acute effects, the immediate symptoms will be discomfort and a sense of oppression, followed by head-

ache and not rarely nausea, and a rather decided rise of temperature, all of which may last for some time even after the individual goes into perfectly pure air. Those who habitually live in such an atmosphere are almost uniformly languid, pallid and anemic, subject to headaches, nausea and loss of appetite, and often to skin disorders, and are undoubtedly markedly predisposed to phthisis, pneumonia, bronchitis, scrofula, rhachitis, etc. Moreover, such an atmosphere apparently favors the rapid spread of, increases the severity of, and retards the convalescence from, such diseases as diphtheria, scarlet fever, measles, typhus, smallpox, etc. This may be due rather to the vitiated atmosphere causing a decrease of bodily resistance and an increase in predisposition to such maladies, than to the accumulation or the actual multiplication by growth of the disease germs in the foul air.

When the condition of the air is very bad, the results may be serious and even fatal, as in the well-known cases of the "Black Hole of Calcutta;" of the prison in which 300 captives of war were crowded after the battle of Austerlitz (260 dying very soon after being placed therein); and of the steamer "Londonderry," in which, of 200 steerage passengers who were temporarily crowded into a cabin (18 x 11 x 7 feet) during a storm of only a few hours' duration, 72 were dead and others dying when the cabin was opened: but in these instances the lack of oxygen may have also been a very important factor in the results.

As regards the influence of combustion-products on health, it will suffice to detail the symptoms resulting from inhalation of the various gases. It will be difficult to show that these gases, together with the coincident soot, have any general effect upon health when escaping into the out-door atmosphere, even when produced in such enormous quantities in cities as has been already indicated. It is possible that the sulphur dioxide and other sulphur gases may predispose to, or aggravate attacks of, bronchitis or asthma in those living in the vicinity of gas-works,

chemical factories, etc., but too little comes from the chimneys of dwelling-houses to do much, if any, harm.

In-doors the case is different, for the gases from lights and fires become more and more concentrated if the ventilation be insufficient. The possible effects of varying percentages of carbon dioxide have been noted. We have no evidence of cases of chronic poisoning by this gas, although, as Parkes says: "The presence of a very large amount of CO_2 in the air may lessen its elimination from the lungs, and thus retain the gas in the blood, and thus in time possibly produce serious alterations in nutrition." It may be said, however, that this author knows of no modern proof of such a result.

In cases of acute poisoning by this gas—*i. e.*, where it is in great excess in the atmosphere—there is an almost immediate loss of muscular power, and the person may consequently be unable to remove himself from the place of danger, while others who go to help him may also succumb and more than one be asphyxiated. Accordingly, volunteer rescuers should always remember to act with coolness and great rapidity, and to provide means for the prompt removal not only of the ones they would save, but of themselves as well. Fortunately, when one who has been overcome by carbon dioxide is brought into an atmosphere of pure air before life is extinct and is aided by artificial respiration, he usually recovers quickly and completely because of the rapid escape of the excess of the gas from the blood and its replacement by the necessary oxygen. Death from carbon dioxide poisoning is probably mainly due to asphyxia, partly from lack of oxygen and partly from paralysis of the respiratory muscles. The latter, as well as the general motor palsy, might seem to indicate that the gas itself had also a positive physiological and toxic effect upon the nerve-centers, did we not remember that cutting off the oxygen supply alone produces a similar effect and that there are like symptoms in carbon monoxide poisoning where there is an internal oxygen starvation characterized by a similar

weakness or paralysis of the extremities, going on in extreme cases to failure of the respiratory muscles and death.

Cases of poisoning by carbon monoxide are much more serious. Recovery from its effects is slow and uncertain, because this gas tenaciously unites with the hemoglobin of the red blood-corpuscles, paralyzing them as it were, and rendering them unable longer to act as oxygen-carriers to the tissues; while the union of carbon dioxide with the blood is always a much less stable one and is readily dissolved as soon as interchange with a normal atmosphere is available. Less than 0.5 per cent. of carbon monoxide in the air has caused symptoms of poisoning, and Rosenau states that "air containing 0.4 per cent. may, in one hour, prove fatal." It appears that when the gas, volume for volume, completely replaces the oxygen in the blood, it cannot again be displaced by oxygen, so that the person dies asphyxiated; but Pokrowsky has shown that it may be gradually converted into carbon dioxide and be got rid of, if the saturation is not too great and life be maintained sufficiently long.

The affinity of carbon monoxide for the hemoglobin of the blood is about three hundred times that of oxygen. It was found by investigations on animals and on men that exposure to 0.06 per cent. of carbon monoxide in air will cause perceptible effects, and exposure to 0.15 per cent. is dangerous to life; that no symptoms are felt when the saturation of the blood with carbon monoxide is below 10 per cent., but that above 20 per cent. the symptoms appear and increase in severity with the increase in blood saturation until with 60 to 70 per cent. saturation death may ensue, and when the saturation is between 70 and 80 per cent. respiratory failure and death occur.[1]

The symptoms of carbonous oxide (monoxide) poisoning are feebleness, oppressed breathing, trembling, and ina-

[1] U. S. Public Health Bulletin No. 150, 1925, p. 54.

bility to swallow; then "loss of consciousness, destruction of reflex action, and finally paralysis of the heart." "Hirt says that at high temperatures (25° to 32° C.=77° to 90° F.) it produces convulsions, but not at low temperatures (8° to 12° C.=46° to 54° F.)." The blood and muscles are made a brilliant red by this gas; darkened by carbon dioxide. Claude Bernard says that a mixture of these gases is more destructive than either separately, probably because the excess of the acid-gas interferes with the conversion of the monoxide and its elimination from the blood, a process that is always slow and uncertain under the best of conditions. On the other hand, it is now common and good practice to add a small amount of carbon dioxide to the oxygen administered to victims of carbon monoxide poisoning, because the carbon dioxide normally stimulates the respiratory center and so tends to increase the intake of oxygen.

A comparatively new source of carbon monoxide gas of considerable danger to the public is from the combustion of gasoline in motor vehicles. Numerous accidental deaths have already been reported due to the escape of the gas from motors allowed to run in closed garages, and in some cases these fatalities have occurred within a very few minutes. The question has also been raised as to the possibility of serious harm to the public because of the discharge of this gas into the atmosphere from the great number of automobiles that frequent our crowded and narrow streets. Statements have been made that traffic policemen have been thus affected by the gas and compelled to shorten their hours of duty on post because of it.

This gas also occurs and must be guarded against in certain industries, as in blast furnaces, and steel mills, and it, or a combination of it with nitrogen, constitutes the dreaded "black damp" of mines.

Illuminating- or coal-gas—composed of hydrogen, light and heavy carburetted hydrogens, a little nitrogen, and carbon dioxide, and from 5 to 7 per cent., or even more,

of carbon monoxide—rapidly causes, when inhaled, giddiness, headache, nausea and vomiting (occasionally), confusion of intellect, loss of consciousness, general weakness and depression, partial paralysis, convulsions, and the usual symptoms of asphyxia. Mixed in large proportions with the air, death may ensue comparatively quickly, probably because of the large content of carbon monoxide. It is well to remember that the so-called water-gas, now so extensively manufactured for fuel purposes and also for diluting coal-gas, contains a much larger percentage of carbon monoxide (sometimes from 30 to 40 per cent.) than coal-gas, and that the effects resulting from inhalation of a mixture of the two will in all likelihood be more marked, more rapid, and more deadly than with undiluted coal-gas. Much harm may likewise occur when even small quantities of this mixed gas are breathed from day to day, and there can scarcely be a doubt that the cause of many of the troublesome anemias might be traced to unnoticed or uncared-for leaks in the gas-pipes of dwellings.

"The effects of constantly inhaling the products of gas combustion may be seen in the case of workmen whose shops are dark and who are compelled to burn gas during a large part of the day; the pallor, or even anemia and general want of tone, which such men show, are owing to the constant inhalation of an atmosphere so impure."

Sulphurous acid-gas (S_2O) and hydrogen sulphide (H_2S) are each fatal to life, the latter when in a comparatively concentrated state; but they are offensive to the senses and thus give warning of their presence, so that there is less danger of their causing serious results. Men can accustom themselves to much larger proportions of hydrogen sulphide in the atmosphere than can animals, but continued exposure to it is liable to give rise to vertigo, headache, slow and weak pulse, sweating, and loss of strength.

When sewer-gas or soil-air escapes into the outer air they are usually soon diluted beyond power for harm;

but if either gains access to closed rooms or unventilated dwellings, its effects upon the inmates may be depressing and harmful. Concentration of the impurities may cause acute symptoms, such as vomiting, purging, severe headache and prostration. Their influence, however, is usually insidious, owing to dilution with the house-air; and the more common symptoms attributable to them will probably be pallor, languor, frequent headache, loss of appetite, diarrhea, impaired health, and often chronic anemia. Children especially may suffer in nutrition, with frequent febrile attacks; but with all, the power of resisting such diseases as typhoid fever, diphtheria, etc., is probably lessened and the susceptibility to them is increased, the sickness more severe, and the convalescence more prolonged. Indeed, sewer-gas and soil-air probably aggravate all diseases.

In this connection Alessi has shown that when small animals, such as rabbits, rats, and guinea-pigs, have been exposed to sewer-air for some days, by far the larger majority when inoculated with only a small quantity of a slightly virulent typhoid culture contract the disease and die, while almost none succumb of those treated similarly in every way excepting by the exposure to sewer-air. He also showed that the inoculations were more deadly when the previous exposure to the noxious gas had been less than two weeks than when it exceeded that period, indicating that animals, as well as persons accustomed to such contamination, are not apt to manifest the symptoms due to it so rapidly or so seriously as are those who experience it for the first time—a fact well known to all observers. It is only fair to say that these experiments of Alessi have apparently been controverted by other observers; but, whichever may be correct, the truth of the following quotation doubtless still holds good:

"There is undoubtedly a poisonous agency at work when sewer-gas is inhaled, which, though it may not directly act, yet so prepares the soil that the system is unable to resist the invading organism when it comes."[1]

[1] Notter and Firth, p. 159.

CHAPTER VI.

VENTILATION AND HEATING.

Although our ideas as to the basic reasons for ventilation have materially changed within recent years, there can be no question as to its continuing importance in maintaining a healthful and agreeable environment in which to live. With the present appreciation of excessive humidity, high temperature and air-stagnation as factors in causing much of the depression and discomfort in poorly ventilated places, any proper definition or system of ventilation must include the alteration or obviation of such conditions and the adjustment of the atmosphere to a state most favorable for physiological comfort and well-being. Former theory and practice gave particular attention to the *composition* of the atmosphere and to the impurities which it might contain, whereas the present tendency is to consider its *condition* as of equal if not greater importance, and to give special attention to the latter in planning modern ventilation systems or equipment.

This does not mean that we are not to endeavor to prevent the admixture of any harmful impurities, whether gases, vapors or dusts, with the air we breathe, or to remove them if already present; but it does mean that we have abandoned the notion that the purpose of ventilation is to provide an ample supply of oxygen or to get rid of an excess of carbon dioxide or even of "crowd-poison," and that we now realize that our comfort and health really depend more upon a gently circulating atmosphere of satisfactory temperature and humidity than upon an ever-changing and over-abundant supply of so-called "fresh air" from without.

There can, of course, be no objection to removing anything in the air that is noxious or disagreeable, if only for

esthetic reasons, nor to the admission of plenty of out-door air when weather conditions permit and when the increase in one's enjoyment or comfort is not overbalanced by excessive fuel waste. But while it is important in certain occupations and places of industry to make abundant provision for the prompt and continuous removal of harmful or offensive atmospheric impurities of every kind, these are not likely to occur in properly constructed and well-managed dwellings. Clean air is of value and is to be desired within all reasonable limits, but making it a fetich does not necessarily advance one's comfort or welfare.

The quantity of air from out-of-doors needed under varying conditions will be considered later. We must not think, however, that we do all that is necessary if we simply renew the in-door air with a fresh supply from without, for unless the source and supply from which we take that which is to replace or dilute the vitiated air be pure and clean any system of ventilation that we may adopt will be of little value.

External Ventilation.—External ventilation of buildings, streets, and cities is of importance, then, as well as that which relates only to the interior of dwellings, workshops, and places of assembly. Numerous investigations and statistics, both here and abroad, show that "the health of a town largely depends upon the width of the streets, the general height of the buildings, and the amount of yard-space at the rear of each which separates it from its opposite neighbor." It is also difficult to overestimate the value of wide streets, numerous diagonal ones and frequent parks or open spaces, especially in the more thickly inhabited portions of a city.

A study of this subject in Philadelphia a number of years ago when tuberculosis was much more prevalent than at present showed a decided preponderance of deaths from this disease in houses on narrow streets as compared with those on wider ones. This, in conjunction with similar results obtained elsewhere, helps to indicate the importance of providing ample opportunity for the free

movement of air and the access of sunshine about our dwellings.

Internal Ventilation. -As regards internal ventilation, it will be well to determine at the outset the meaning and limitations of the term. Many years ago Parkes said: "It will be desirable to restrict the term ventilation to the removal or dilution, by a supply of pure air, of the pulmonary and cutaneous exhalations of men, and of the products of combustion of lights in ordinary dwellings, to which must be added in hospitals, the additional effluvia which proceed from the persons and discharges of the sick. All other causes of impurity of air ought to be excluded by cleanliness, proper removal of solid or liquid excreta, and attention to the conditions surrounding dwellings." With the function of ventilation thus limited, it will not be necessary to make provision for such an abundant supply of pure air as might otherwise seem advisable. It is evident also that the purity of in-door air must almost always be relative and not absolute, especially in a climate like ours, which for a considerable portion of the year necessitates warming of the air and some consequent economy in its use.

Considering the problems of atmospheric improvement, from the standpoint of composition or content, two factors must be determined in order to discover the quantity of air desirable and consistent with the requirements of good ventilation and the maintenance of health whenever any positive factor of contamination is likely to be present: (*a*) the *extent* to which the air of a room is contaminated in a given time by the impurity it receives, and (*b*) the *limit of permissible impurity* beyond which there will be a possible risk or detriment to health. In accordance with the above-mentioned limitations of Parkes, the contaminating substances will usually be comparatively few in number, but the same factors are to be sought in the case of any detrimental substances in the atmosphere at any time, provided their source or cause cannot be directly removed.

The foregoing statement, which is correct in principle, has, through fallacious assumption, led to probably unwise or unnecessary ventilation requirements in the past. Thus, when human effluvia or the so-called "crowd-poison" was considered to be ordinarily the most harmful as well as the most offensive constituent in the atmosphere of dwellings, it was naturally thought essential that we should know not only the quantity present at any given time but also the limit to which it should be reduced to be consistent with health.

Now although it is extremely difficult to determine quantitatively the organic matter given off by human exhalation in any given time, the carbon dioxide, as has been stated, is usually exhaled in a reasonably constant ratio with it, and may therefore be used as an *index* of the amount of it contaminating the air. Taking Pettenkofer's figures, which have been substantially confirmed by other investigators, viz., 0.6 cubic foot of carbon dioxide per hour per head for a mixed assemblage at rest, 0.7 cubic foot for adult males, and increasing amounts according to the physical work done, we have the first factor (*a*) of our problem determined for all cases where the products of human respiration and exhalation are the only contaminants.

In establishing the limit of permissible impurity—the second factor (*b*)—it will naturally be advisable to require that the supply of air from without shall be sufficient not only to be thoroughly consistent with health, but also that there may be no perception of impurity by the senses, the air of the room remaining apparently as fresh and pure as that out-of-doors. To this end De Chaumont made a large number of observations (over 450), and found that as long as the carbon dioxide due solely to respiratory impurity did not exceed 0.02 per cent., the in-door air did not differ sensibly from that without, but that when the respiratory CO_2 reached 0.04 per cent. the air was rather "close" and the organic matter was becoming perceptible to the sense of smell. Subsequent investigations appeared to

indicate that as long as the respiratory CO_2 did not exceed 0.02 per cent. the atmospheric conditions had no perceptible effect upon health.[1] Consequently, this amount of carbon dioxide, over and above the amount normally present at the time in the outer atmosphere was taken as the index of the limit of organic atmospheric impurity from human bodies permissible in ordinary inhabited apartments.

Having now the two factors of the problem, and provided there are no other sources of contamination, it apparently becomes a simple matter of proportion to determine the quantity of fresh air to be supplied to each individual. The equivalent of 0.02 per cent. is 0.0002 cubic foot of carbon dioxide in each cubic foot of air, or 2 parts in 10,000. In a mixed assembly at rest each person exhales 0.6 cubic foot of carbon dioxide per hour. Consequently, to dilute properly this respiratory CO_2 and its coincident organic effluvia, each person will need $\frac{0.6}{0.0002}$ or 3000 cubic feet of fresh air per hour. If the individuals are all adult males, or if they are working, there must be a corresponding increase in the air supplied, running up to 6000 or even 9000 cubic feet or more per head in certain laborious occupations.

Under the assumption that it is necessary to dilute a harmful substance, the "crowd-poison," this is the theoretical amount of pure air requisite for good ventilation and ventilation practice was based upon it for a long time. But in practice we find that we can get along in safety and comfort with considerably less, not only because some of the bodily impurities are almost at once carried away and out of the room by the draughts through the exits, or through the cracks and crevices in the walls and

[1] This may simply mean that the air movement is sufficient not only to obviate the concomitant factors of excessive heat, humidity and stagnation, but also to reduce the organic matter to an amount or proportion imperceptible to the senses and innocuous to the human economy.

ceiling which act as exits, and the incoming air does not, therefore, have to mix with and dilute that portion of the impurities that is so immediately removed, and because lesser currents of air stimulate the skin, favor evaporation, cool the body and obviate stagnation, which is one of the depressing factors already mentioned, but because we now know that the human exhalations and effluvia are not nearly so harmful as they were considered to be, and that we really need only to dilute them below the degree of perceptible offensiveness. We need not attempt to determine here wherein the deductions of De Chaumont were fallacious, because the point of view as to the basic reasons for ventilation have changed so markedly, but we can accept the modern doctrine that sufficient change of air to keep the atmosphere about us agreeable to the senses is all that is necessary as far as the factors of "crowd-poison" and "respiratory" carbon dioxide are concerned.

The foregoing is not meant to imply that an abundance of fresh air is not desirable whenever climatic or temperature conditions permit its introduction without discomfort to the inmates or an excessive expenditure of fuel, but it should be realized that intemperate zeal for fresh air may at times do more harm than good. For example, a supply of 1800 cubic feet per hour or 30 per minute for each pupil has heretofore been considered necessary for the normal ventilation of school buildings, and some states have gone so far as to make that a legal requirement in school administration, but a bulletin of the annual meeting of the American Public Health Association in October, 1925, stated that "Hundreds of thousands of dollars are wasted every year on this continent in the installation and operation of systems of school ventilation that are not only not beneficial but positively harmful to the health of school children. In the light of current knowledge, the supply of as large an air volume in school-rooms as 30 cubic feet per minute per capita is necessarily accompanied with dangerous overheating of the school-room in

order to avoid resulting drafts," and the Association at the same meeting adopted the following resolution:

"That the system of ventilating school-rooms by fresh untreated out-door air admitted at the windows, with gravity exhaust ducts for removing vitiated air from near the ceiling, is the most generally satisfactory method of school ventilation.

"That state and city regulations interfering with such scientific and economical methods of school ventilation should be repealed in the interests of public health."

In the sick-rooms and hospitals more fresh air is needed than in ordinary rooms and dwellings because the organic effluvia from the sick is much more offensive and noticeable by the senses than that from the well, so that it is a good rule to give the sick-room abundant ventilation or to the extent that the incoming air can be properly warmed and distributed. This is apart from the modern fresh-air treatment of many diseases, which is to be looked upon as a therapeutic rather than a hygienic measure; nevertheless, it is difficult to make a sharp distinction between the two, so that it may be stated that good ventilation of hospitals and sick-rooms is always essential and desirable.

Wherever there are other sources of atmospheric contamination or vitiation, provision must be made for adequately diluting the impurities from them, provided the mixing of the latter with the air cannot otherwise be prevented. Thus, provision should be made for a supply of air sufficient to bring below the limit of permissible impurity any products of combustion, harmful gases, vapors and dusts of occupations, etc., that cannot be removed at the time and place of production. What this quantity of air should be in any case cannot, of course, be foretold without knowing all the conditions, but it should not be excessive for any dwelling with proper and modern equipment for heating, lighting, etc. What is essential is to keep the house-air free of offensive odors and agreeable to the senses and to be certain that there is no opportunity for contamination by harmful gases, such

as carbon monoxide, that are odorless and fail to give due warning of their presence.

The use of the following formula will often be of advantage in solving problems relating to ventilation, viz.: $\frac{e}{r}=d$, where e represents the amount of carbonic acid or other impurity added to the atmosphere in the given time, r the relative ratio of the impurity in parts per cubic foot, and d the delivery or volume of fresh air in cubic feet.[1] Example: What will be the respiratory impurity in the air of a room of 3000 cubic feet capacity which has been occupied by three men for two hours, supposing that there has been an ingress of 9000 cubic feet of fresh air in that time? Here

$$e=0.7\times 3\times 2=4.2, \text{ and } d=3000+9000=12{,}000.$$

$$\frac{4.2}{r}=12{,}000: \quad \frac{4.2}{12{,}000}=r=0.00035=$$

0.035 per cent. of carbon dioxide.

Before considering the means by which a sufficient quantity of pure air may be supplied to buildings and apartments, it will be well to note the following restrictions as to the size and height of the rooms. If a room be too small, the air therein will have to be changed often, the velocity at the inlets will be increased, uncomfortable draughts will be created, and the air will not diffuse itself so thoroughly throughout the room. Experience shows that even when the air is properly warmed, it cannot be changed much oftener than three times an hour without discomfort to the occupants of the room, unless the ventilating apparatus be very perfect in its workings and therefore expensive. Consequently, if we take, as we formerly did, 3000 cubic feet of fresh air to be the amount required per person per hour, the *cubic space* per individual should be 1000 cubic feet; but, as a matter of fact, a somewhat lesser space is sufficient for ordinary needs.

[1] By allowing e to represent the total contamination per hour, and r to represent the limit or extent of impurity in any given case, this formula can be used for almost any other ventilation problem, whatever may be the contaminants or source of impurity.

Again, it must be remembered that the difficulty of securing equable heating and ventilation increases with the height of the room above a certain limit, and that with the sick especially a certain amount of *floor-space* is necessary, both for the separation of patients and for convenience of attendance. Ten or twelve feet will usually be found to be the safe limit of height for all apartments intended for continuous rather than temporary occupation, and consequently there should be a minimum allowance of from 65 to 80 or more square feet of floor-space per head, and even an increase above this in workshops, hospitals, etc. However, there is no objection to high ceilings if one is not limited as to floor-space, pure air-supply, and heat; and they are even advisable in rooms where many lights are to be burned. Again, these restrictions regarding cubic- and floor-space do not necessarily apply to such buildings as churches, theatres, etc., which are occupied for only a comparatively limited time, which can be thoroughly flushed out after use, and in which it is evidently impracticable to allot to each person the above floor-area. Yet pains must be taken in such assemblies to keep the atmosphere in satisfactory condition by whatever means are necessary; while for school-rooms and the like there must be extreme care that the pupils are not overcrowded, and that they have a full supply of clean air.

Any correct system of ventilation, in addition to the above considerations, must take into account the source of the air supplied, the distribution, the heating or cooling of the air when necessary, and its relative humidity.

The air supplied to any dwelling should be taken from well above the level of the ground, where it is free from contamination and is constantly changing, and not from cellars or closed areas, where the atmosphere is stagnant and full of impurities. The conduits leading to the heating or ventilating apparatus should also be so arranged that they may be frequently and readily cleaned. It is well to have them covered with gratings to prevent

objects being thrust into them, and in some cases it may even be advisable to filter the air through coarse cloth or fine wire gauze to free it from dust and other impurities. In the mechanical system of ventilation adopted in the chemical laboratory of University College, Dundee, the air is filtered by being passed through jute cloth (light Hessian) stretched on frames seventeen feet long by four feet wide. In this case the presence of the screen actually increased the delivery of the air by nearly 10 per cent., probably by preventing eddies. The screens collected two and one-half pounds of dirt in seven weeks. They last about a year, and the cost is about 2*d* (four cents) a yard.[1]

The air may be kept in motion and efficient ventilation secured (1) by those forces more or less continually acting in nature, producing *natural ventilation*, and (2) by these in combination with other forces set in action by man, giving *artificial ventilation.*

Natural Ventilation.—The three main forces of natural ventilation are diffusion, the winds, and the motion caused by the difference in weight of volumes of air of different temperatures. Diffusion is constantly taking place between all the gaseous constituents and impurities of the air, and even effects a change through brick and stone walls, but it alone is insufficient to keep the air pure, although it does much to further this. Moreover, as suspended matters are solid, not gaseous, they are not changed or removed by it. However, the action of this force should not be ignored in our calculations as being insignificant, for it is not only continuous, but it also affects the whole volume of the atmosphere in maintaining its uniformity of composition. "Roscoe found that when he evolved carbon dioxide in a room, the amount had decreased one-half from that cause (diffusion) in ninety minutes."[2]

As the rate of diffusion is inversely as the square

[1] Stevenson and Murphy, vol. i, p. 51.
[2] Notter and Firth, p. 194.

roots of the densities of the gases concerned, the interchange goes on rapidly when there is much difference of temperature between the in-door and outer air, and also at the top of rooms, where the warm impurities tend to accumulate.

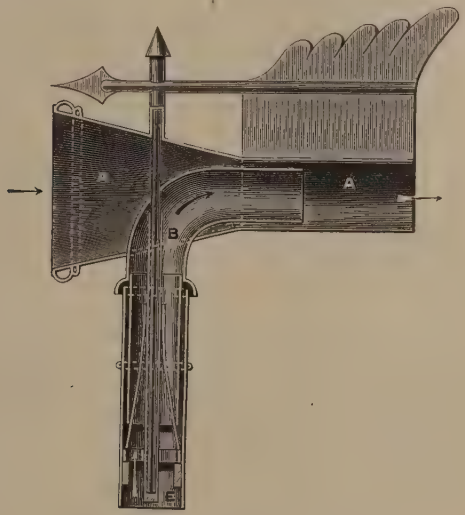


FIG. 20.—Cowl or ventilator for aspiration.

Winds are powerful agents for ventilation, and a slight breeze passing through a room changes the air therein many times in the course of an hour, and carries out by its force many of the solid impurities not affected by diffusion. Wind will pass through walls of wood, brick, or stone, although its progress is markedly arrested by much moisture in the walls and by paper or plaster. The average rate of movement of the wind is considerable, but the disadvantages in utilizing it in ventilation are the uncertainty of its direction and velocity, the difficulty of

regulating it, and the fact that it may fail us at a time when we most need its action. In winter it usually has to be excluded directly from our houses, because a velocity of five or six feet per second is not comfortable unless the air be previously warmed. We may, however, take advantage of the facts that a small current with a high velocity will set in motion a larger volume of air, and that wind blowing across the top of a tube will cause an upward movement of air in the tube. This is one reason why there is almost always a draught up an unused chimney and why it usually acts as a good ventilating outlet.

To utilize these perflating and aspirating powers of the wind, and to prevent back-draughts down chimneys and ventilating pipes, we make use of so-called *ventilators* or *cowls*, either movable or fixed. We can so arrange these that the force of the wind either drives air into the building (perflation) or draws air out of it (aspiration). Very good systems employing these have been put in operation, the incoming air being warmed, when necessary, by passing it over stoves, steam coils, etc., and they are especially useful where the inner air is colder than that externally, and where artificial methods of ventilation dependent upon heat cannot be employed, as in the holds of ships, deep basements, etc.

The most important agent in natural ventilation is, however, the movement produced by variations in the specific gravity of air. Although the wind might be included under this head, being produced by the same force, the air is moved independently of the wind, especially in closed buildings. As the air expands when heated, it becomes lighter, volume for volume, and rises because the colder, heavier air pushes in beneath to occupy the space. Now in all inhabited apartments a warming of the atmosphere is continually taking place, not only by means of the lights and heating apparatus, but also by the bodies of the occupants. The consequent movement is therefore a continual though not necessarily an equable one, varying as it does with the temperature of the out-door air and

the number and intensity of the heating agents within. There being such a warming and movement of the air, it follows that, unless a room be perfectly air-tight, some of the apertures will act as inlets and others as outlets, and the quantity flowing out of the room will be practically equivalent to that flowing into it. Therefore, though this force may not be so powerful or efficient as strong winds at certain times, yet being more constant, more readily determined or calculated, and more controllable, it is the one most to be considered in arranging a system of ventilation.

To determine the velocity of the influx or outgo of air, we make use of the law that a fluid passes through an opening in a partition between two volumes of the fluid with the velocity which a body would acquire in falling from a height equal to the difference in level of the fluid on the two sides of the partition. In the case of a current of air we substitute for the difference of level the difference in pressure on the two sides of the partition or opening, and this is expressed by the difference in temperature multiplied by the difference in height of the openings of entrance and exit, and divided by 491, $\frac{1}{491}$ representing the expansion of the atmosphere in volume and the lessening of density for each degree (Fahrenheit) of rise in temperature. The velocity will therefore equal

$$8\sqrt{\frac{\text{(diff. in temp.)} \times \text{(diff. in height)}.}{491}}$$

Example: What is the velocity of the current in a chimney 40 feet high, the out-door temperature being 20° F. and in-doors 70° F.? Answer:

$$V = 8\sqrt{\frac{50 \times 40}{491}} = 8 \times 2 +, \text{ or about 16 feet per second.}$$

In actual practice use is made of a table derived from this formula, or else the velocity is determined directly by means of the *anemometer*. Allowance must be made

for the friction of the air against the sides of the ducts and against itself, amounting to from one-fourth to one-half of the theoretical delivery, according to the length, size, straightness, etc., of the inlets and outlets. The friction will be inversely as the diameter of the openings and directly as the length of the tubes; the shape of the openings also affects it, and right angles diminish the current one-half. Accumulations of dust and dirt in air conduits greatly lessen the velocity.

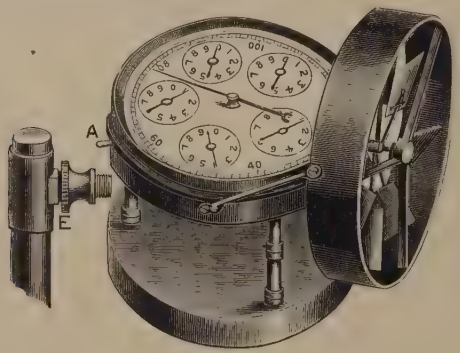


FIG. 21.—Anemometer, used for measuring the velocity of air-currents directly; *A*, slide for releasing or stopping the dial hands; *E*, support for attaching the instrument to a staff or cane.

The average velocity multiplied by the total area of the inlets or outlets, with a proper allowance for friction, will give the quantity of air passing through the rooms or series of rooms in any given time.

One of the most difficult problems in natural ventilation is to secure a uniform distribution of fresh air through the rooms, and where this is desirable, to remove the used air as fast as the fresh air is supplied, thus preventing its mixing with the latter. Certain circumstances always make the question complicated: the size and number of inlets and outlets, the rate and direction of motion, and the forces

acting to produce the movement must always be subject to constant change, and must thus constantly alter the result. In fact, it is practically impossible to devise a plan that will satisfy all conditions at all times, and the best that can be done is to select that one which will give the greatest efficiency and most satisfactory results under all ordinary circumstances.

The force of diffusion will always act as long as there is any difference of temperature and any communication between the exterior and interior, and no special attention need be given to it. For reasons already given, we cannot use the wind continually, but we should employ it whenever possible by opening doors and windows, on account of its great power for sweeping out solid impurities and "crowd-poison" and thoroughly changing the air. In cold weather, currents from windows, etc., should be directed toward the ceiling, so that they may be diffused and partially warmed before reaching the inmates of the room. Numerous devices have been suggested for introducing unwarmed out-door air without discomfort, or for diffusing it through the room: among these may be mentioned perforated bricks, or double-paned windows, valves, screws, etc. A cheap and satisfactory temporary arrangement is to place a board about four inches wide and as long as the width of the lower window-sash beneath the latter. Or, better, have a light frame covered with fine netting or wire-gauze, four or five inches wide, made to fit above the upper sash: the fresh air from without can now enter freely between the upper and lower sash, being reflected upward by the inner surface of the glass in the upper sash, and thus mixing with warm air before reaching the occupants of the room; while the frame at the top of the window becomes an outlet for the foul air and also serves to keep out flies and mosquitoes, the interference of the netting or gauze preventing too rapid an outgo and consequent loss of heat. Another excellent and inexpensive device is a board as long as the width of the window and eight or ten inches wide which is placed

so that its lower edge rests on the window sill and it slants inwardly, being held in place by V-shaped pieces attached to the window frame at each end. When the window sash is raised the cool, incoming air is deflected upward by the sloping board so that it is practically unnoticeable a short distance from the window. By making suitable grooves in the end pieces, a sheet of clear or translucent glass may be substituted for the board, thus admitting a full supply of light and improving the appearance of the device. (Fig. 22.)

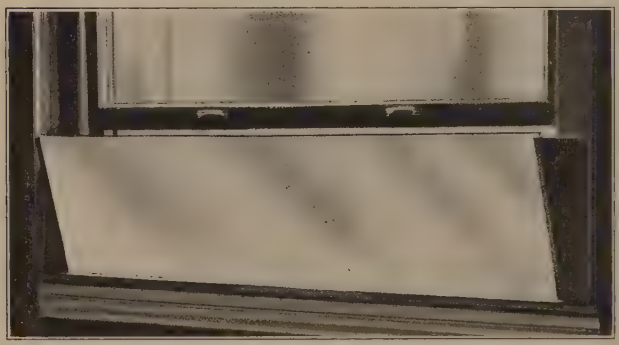


FIG. 22.—Window ventilator with translucent glass instead of board.

But in a climate such as our own, and in all cold countries, special measures must be taken during a large part of the year for warming the out-door air before introducing it into occupied rooms.

Where we intend to depend most upon the third force of natural ventilation, viz., the movement caused by unequal weights of air, we must provide other openings for the entrance and exit of the air than the windows and doors, so that there will be a practically constant movement through the rooms in a given direction, that we may be sure the air is from a pure source, and that we may get the utmost service from our appliances.

There is considerable difference of opinion as to the best locations for inlets and outlets, and as the conditions are necessarily different in every case and so many factors are to be considered, it is difficult to lay down general rules. It should be an aim, however, to have the air well distributed throughout the room or rooms and to have no direct draughts from the inlets either upon the occupants or to the outlets. It is the writer's opinion

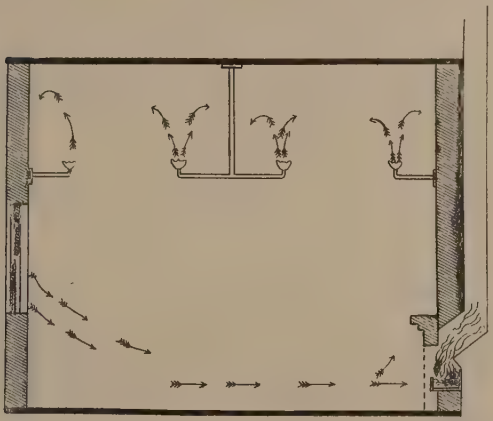


FIG. 23.—Direction of air-currents in room lighted by gas and heated by open grate.

that usually the outlets should be located near the top of the room, owing to the tendency of the used air to rise, and because in unventilated rooms the foulest air for some time after its contamination will be found nearest the ceiling. The products of combustion from lights, etc., will also practically all be in the upper strata of air. (Fig. 23.) If, however, provision is or can be made for a constant and sufficiently strong aspirating force in the outlet ducts, it may be advisable to withdraw the used

air from near the floor level and below the inlet openings, though not in too close proximity to them, since in this way a more thorough distribution of the incoming air and a greater dispersion of its contained heat are secured. This is aptly shown in the illustration depicting the currents in a room heated by a ventilating grate. (Fig. 24.) This principle is also involved in the Smead system of ventilation and heating, which still further serves economy by carrying the used air beneath the floor of the room from which it is taken, thus warming the floor with some of the

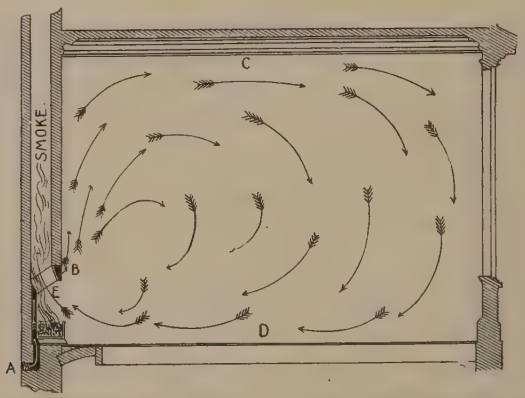


FIG. 24.—Direction of air-currents in room heated by a ventilating grate.

heat the waste air yet contains and securing the utmost benefit and service from the fuel. (Fig. 25.)

The location of the inlets should depend on the temperature of the incoming air; if it is cold, it should be admitted some considerable distance above the floor, so that it may diffuse and be partially warmed before reaching the inmates of the room; if it is warmed, it may come in near the floor or below the middle level of the room.

Where much fresh air is required, it is better to have a number of inlets and outlets than one large one of each, as the distribution is then more certain. The total area of the outlets may be the same as that of the inlets, as the expansion of the air is scarcely sufficiently great to require a difference. The outlets should all be on the same level; otherwise the highest one will be the one of greatest discharge, and often the only one, the others possibly acting as inlets and drawing air from an impure source. As the temperature varies from time to time, and with it the current, some arrangement is needed for regulating the size of the openings of the inlets or outlets to suit the varying conditions. To supply 2400 cubic feet of air per head per hour a velocity of 4 feet per second will require an inlet opening of 24 square inches for each person; a larger volume requires a larger opening, as a velocity of 5 feet per second is uncomfortable unless the air be well warmed. Outlet tubes should always be protected from cold and kept as warm as possible.

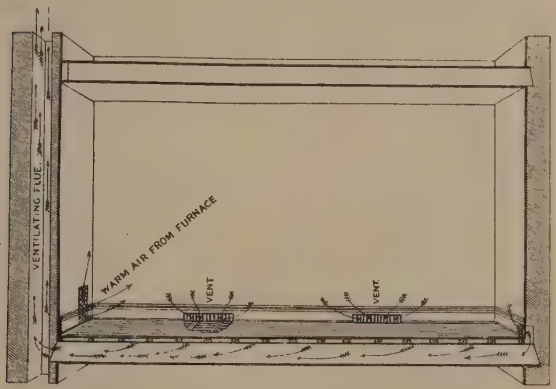


FIG. 25.—Illustrating the Smead system of ventilation.

As long as there is a fire in a grate or stove connected

with a chimney there will be a constant upward current in the latter; and the area of the chimney's cross-section being known, and the velocity determined by the ane-

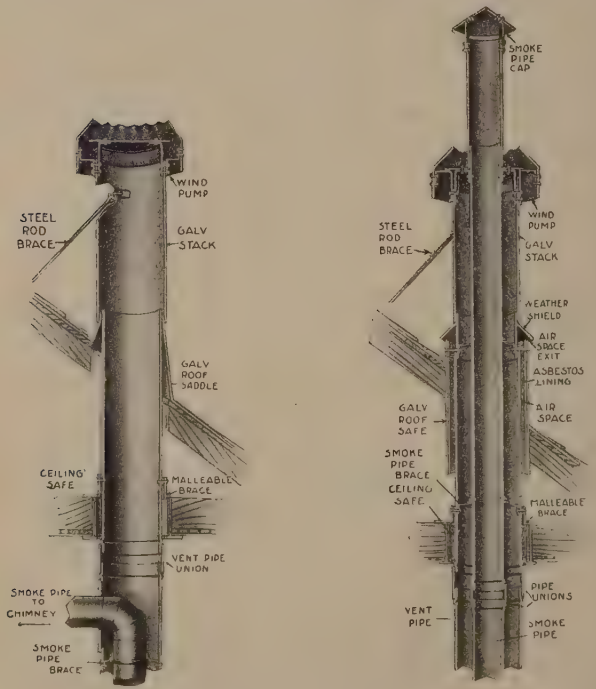


FIG. 26.—Outlet ducts warmed by stove-pipes.

mometer or by calculation, as already indicated, the amount of air passing out of the room in this way may readily be determined. In this connection it may be stated that a chimney may thus act as the only outlet, and

all other openings into the room may serve as inlets, especially when the fire is brisk, the outgoing current, of course, being practically equivalent to the amount of incoming air. Moreover, the outgoing current may be so strong as to overtax the capacity of the inlets, in which case more or less of a vacuum will be created within, so that the outside pressure may cause down draughts in the chimney from time to time and a driving back of the smoke and gases from the fire into the room. The obvious remedy is to enlarge the inlet area by opening a door or window, or to lessen the exit draught by means of a damper in the chimney. On the other hand, the inlets may be so large and the current so strong that the air coming into the room cannot be properly warmed, in which case, again, the size of the outlet should be lessened by a damper, or there should be an increase in the efficiency of the heating apparatus.

When we wish to draw air from distant and non-communicating rooms, the ducts may be led into a chimney below or just above a fire, or, better, into a flue or shaft alongside or encircling the heated chimney. When the exit ducts open into a chimney or smoke-stack the draught is greater just above a fire than below it, but the conduits should not enter near the top of the chimney, for there the extracting power is not so great and there is danger of high winds blowing smoke and foul air back into the rooms. Outlet flues may be constructed alongside chimneys that are being constantly used; they should be as smooth as possible interiorly, and should be as high as the adjoining chimney, to avoid down draughts. The openings from the rooms into these ducts should be as near the ceiling as possible, to get the benefit of the higher temperature of the upper strata of air, unless, as previously indicated, there is certainty of the extracting force being constant and sufficiently strong, when the air may be taken from a lower level. (Fig. 27.)

Artificial Ventilation.—Artificial ventilation is that which is brought about by the intentional application of the above-

mentioned and other forces, and by means of special mechanical apparatus and devices, in contradistinction to natural ventilation, which may act independently of human cogni-

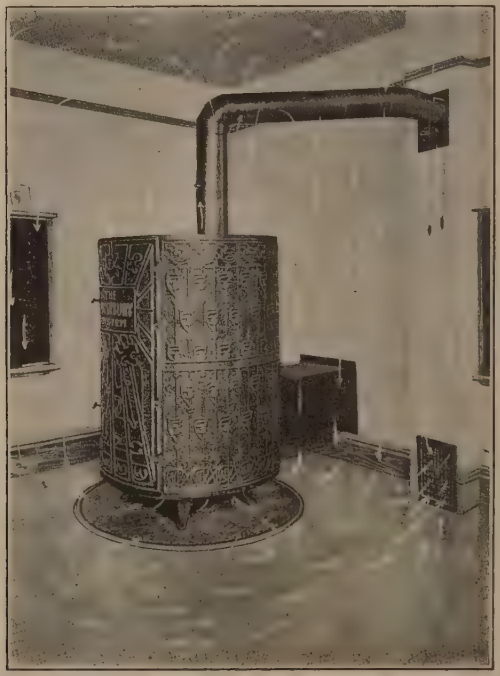


FIG. 27.—Waterbury ventilating stove, showing encircling drum, inlet for out-door air, and outlet for impure air into chimney.

zance and intention. It consists in either extracting air from, or forcing it into, a room or building, or in both together. The object may be attained by heating the air by special apparatus in the outlet, or by warming the outlet itself

or by the use of a fan, a screw, or a steam- or water-jet in either the inlet or outlet.

In hospitals and other places where a constant and independent supply of heat can be afforded, extraction shafts apart from chimneys may be used. These extraction shafts may be heated by fires, steam pipes, or steam-jets at the bottom, or by steam or hot-water pipes coiled around the sides. Some system like the following is sometimes used in mines where large quantities of air must be extracted. There are an entrance and an extraction shaft; large fires are constantly maintained at the bottom of the latter, the air is drawn down the former, diverted through all parts of the mine by partitions, and finally heated and carried up the extraction shaft.

We may also use a jet of steam or water in place of heat to extract air through a shaft, the openings of the foul-air ducts being just behind the jet. It is said that a steam-jet may thus set in motion over two hundred times its own bulk of air. Lastly, fans driven by electricity, steam- or water-power are employed to extract the air, though these are usually more efficient in forcing in air. One of 36 inches diameter at 600 revolutions per minute will propel or extract over 18,000 cubic feet of air per minute.

In ventilation by propulsion or driving in air, these large revolving fans are generally used. The advantages of this, the *plenum*, system of ventilating are the certainty as to the direction of current and amount of air supplied and the ease with which the quantity can be altered or measured as well as warmed; also, by maintaining a slight excess of supply, leakage into the rooms of cold or foul air from without is prevented. The disadvantages are the high cost of power in most cases, the inconvenience or danger from prolonged stoppage from accidents to the apparatus, and some difficulty in distributing the air. For instance, if it be forced in through small openings or at too great a velocity, it will not mix properly with the air of the room. This last objection can usually be obviated by giving special attention to the size, direction,

and arrangement of the inlet flues, and the relative location, size, etc., of both the inlet and outlet openings. The increased use of electric motors and lowered cost of running them is tending to make this system of ventilation more common than in the past.

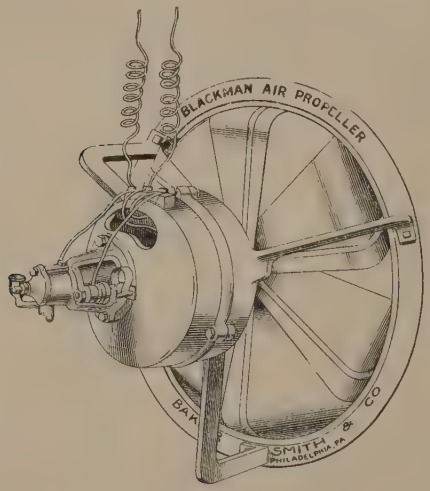


FIG. 28.—Air propeller, with electric motor attached.

In very large buildings it may be advisable or necessary to combine the plenum or propulsion with the exhaust or vacuum system, using power fans both to drive in and to force out large volumes of air. In this way an almost ideal ventilation may be secured, provided the incoming air be clean and be sufficiently warmed by means of steam or hot-water coils or radiators.

Parkes and Kenwood summarize the essential and practical points of ventilation as follows:

"1. When air is heated, it expands and tends to rise; when air is cooled, it contracts and tends to fall.

"2. Cold air tends to enter a room and to move about very much as water would; and this holds true so long as the temperature of the fresh air remains lower than that in the room.

"3. The extent of inlet provision is not quite of the same importance as that for the exit of foul air; for if foul air is extracted in sufficient quantities, fresh air will enter somehow to replace it, as by skirtings, crevices in doors or windows, or even through brick-work in walls.

"4. While the inlet provision for fresh air should average 24 square inches for each individual, several small inlets not too near each other are preferable to one large one; and the provision of inlet areas somewhat larger than those of exit tends to minimize draughts.

"5. Inlets should be as low in the room as possible—*i. e.*, just above the floor (so as not to raise the dust)—if the outside air is warm or has been warmed prior to entry; but at a height of five feet or more if the outside air is cold: otherwise unpleasant draughts are experienced. As a further protection against unpleasant draughts when cold air is admitted, the incoming air should be directed upward; while hot air, since it tends to rise, should be directed downward.

"6. Outlets should be as high as possible, and preferably close to or in the ceiling; and they should have their extractive powers maintained by means of heat or of an exhaust fan, or they are liable to act as inlets.

"7. If possible, outlets should be so placed that vitiated air is drawn toward them before mixing with the general air of the room.

"8. The tendency for fresh air to take a direct course to the outlets must be overcome by judicious selection of the positions of inlets and outlets.

"9. Methods of ventilation devised to ventilate *crowded* premises are generally inefficient unless the incoming air can be warmed in winter to about 60° F.; for efficient

ventilation by cold air cannot be tolerated, and there is a great tendency among workers to close all ventilating inlets.

"10. With less than 250 cubic feet of space for each person, ventilation can never be satisfactory without the aid of mechanical force.

"11. The source of the incoming air should be considered. It should not be borrowed from adjoining rooms, but taken directly from the outside. One great advantage of the more expensive mechanical system of ventilation is the fact that sufficient air can always be obtained from a source that is known and selected.

"12. Ventilation dependent on the extraction of foul air is more convenient and satisfactory than that in which propulsion is mainly relied upon; but the purity of the air is not provided for so easily.

"13. Warmed air forced into a room should be raised only to a temperature sufficient to prevent a feeling of cold (about 60° F.). More highly heated air is often felt to be overdry and unpleasant."

HOUSE-WARMING.

In cold countries there must be some resort to artificial heat in the winter season, and as this subject is more or less inseparably and closely connected with ventilation, it may be appropriately considered at this time. Cold is depressing, uncomfortable, and sometimes dangerous to the young and aged and to women whose habits of life keep them much in-doors, though well-fed, healthy adult men may not be much affected if accustomed to it. In this country we seem to need a higher temperature in our houses than in Great Britain, on account of our drier climate and especially because we keep the atmosphere of our dwellings much too dry; evaporation and consequent cooling of the body take place more rapidly here, and so, while they are accustomed to a temperature of from 60° to 65° F., we find from 65° to 75° F. to be no

more than comfortable. If, however, the relative humidity is maintained at from 50 to 60 per cent., a temperature of 68° F. or even lower will usually be found quite as comfortable and more healthful than a much higher one in a dry atmosphere. A low relative humidity is as unhygienic as one too high.

It needs but slight investigation to determine that we practically make use of but two kinds of heat—radiant and convected—in the warming of houses, and that of these the latter is by far the more generally employed and the more economical. *Radiant* heat, although it is considered to be the more healthful as it warms an object directly without raising the temperature of the intervening air, has the disadvantages of utilizing but a small proportion of the fuel-value, of decreasing directly as the square of the distance of the object from the source of heat, and of thus being available only in comparatively small apartments. Our best example of radiant heat is that which comes from open fires, though any highly heated object, as a stove, gives off more or less of it.

Heat that is carried from one place to another by warmed masses of air, water, or steam is said to be *convected*, and because of the economy in its use and the ease of distribution, especially in large spaces, it is the kind most generally used. *Conducted* heat, which passes from molecule to molecule of the conducting substance, acts too slowly to be available to any extent in house-heating and may therefore be omitted from this discussion.

Just here it may be remarked that under our former theory, when we thought it essential to remove the carbon dioxide and "crowd-poison" as speedily as possible, there were three things, any two of which we might have in cold climates or weather, but not all three together except in rare instances; viz., good ventilation, efficient heating, and low expense. The reason for this was that any approved system of ventilation necessarily and continually carried off a large quantity of air, and the heat it contained, which was lost for warming purposes, had to be replaced

at the expense of more fuel. A heat-unit cannot be used at the same time to produce ventilation and to warm objects other than the air it keeps in motion. On the other hand, the principal aim today in establishing any system of combined ventilation and heating must be to keep the atmosphere of the proper humidity as well as temperature and in gentle motion, to introduce, warm and carry off no more air than is necessary for the requirements of good ventilation and health, and to produce the heat for warming this air and the house itself as economically as possible, though care must also be had to secure evenness of distribution, absence of uncomfortable draughts, etc.

The usual appliances for house-heating are open grates or fireplaces, stoves, and hot-air, steam, and hot-water furnaces. To these may now be added electrical heaters, but the cost of maintaining the latter prevents their use at present by any but the wealthy, except in small apartments or where one needs or can make use of some near-at-hand source of radiant heat.

Ordinary grates and open fireplaces give practically only radiant heat, and render available only from 7 to 12 per cent. of the fuel efficiency. They also heat directly only the surfaces facing them of objects in the room, leaving the remainder cold, and by reason of the strong current up the chimney are also apt to bring in large quantities of air from without that has not been properly warmed, and thus to cause chilling and injurious draughts. Where there is some additional means of heating the air before it enters the apartment and where the chimney current is controlled by a damper, they are valuable, not only for the good ventilation they thus produce, but for the pleasing effect of the exposed fire as well.

But if there be no additional or accessory heating apparatus, such a fireplace cannot be said to give *good* ventilation, even though large volumes of air pass up the chimney, for this air, entering unwarmed from without, sweeps across the floor of the room as a shallow, cold layer much below the level of the breathing apparatus of

the inmates; while the more or less contaminated air above this cold stratum remains undiluted and unchanged. (See Fig. 23.)

To make open grates more effective for heating, the sides and top should be inclined to the back at an angle of 135 degrees, so as to throw as many heat-rays as possible into the room; the fuel surface should be concentrated, and there should be a damper to prevent too rapid combustion and too much heat and air escaping up the chimney. It is to be understood, of course, that the objects warmed by the radiant heat of the open fire do in turn give convected heat by warming the air surrounding them.

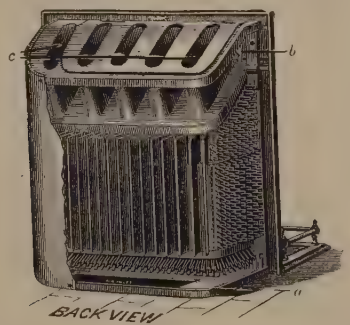


FIG. 29.—Jackson's ventilating grate. The outer casing is cut away to show space and surface for warming the incoming air. The air enters through the oblong inlet (*a*) and passes to the register opening (*b*) (in front) between and around the five smoke-pipes (*c*) above.

If, however, the back and sides of these grates be surrounded by a space through which air can pass and be warmed by the heat that would otherwise be wasted, we shall have a much more satisfactory apparatus, since we thus get both radiant and convected heat and may obtain from 25 to 35 per cent. of the fuel efficiency. (Fig. 29.) And if clean out-door air be led into this air-space and thus

warmed before entering the room, the ventilation will be greatly improved (see Fig. 24), other inlets will be unnecessary, uncomfortable draughts will be avoided, and there will be sufficient heat provided for one or more apartments of moderate size. The air-chamber at the back should not be too small, and there should be as much heated surface to warm the incoming air as possible.

Stoves utilize a considerable percentage of the fuel—75 to 80 per cent. or more—but do not remove much air;

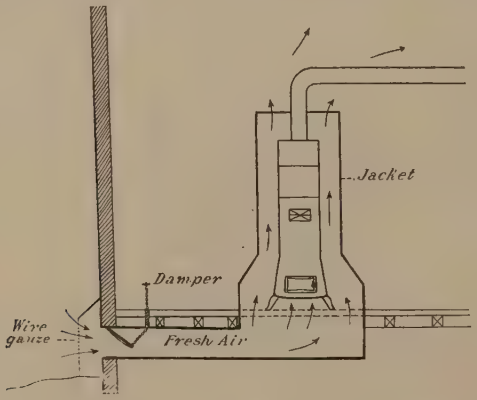


FIG. 30.—Jacketed ventilating stove. (Harrington.)

so ventilation has to be provided for in some other way and is apt to be neglected. Stoves may also give off dangerous gases and products of combustion if not properly cared for or if the damper in the stove-pipe be entirely closed. There should be as much surface exposed as is possible without diminishing the combustion, so that there may be increased radiation and that much air may be warmed moderately rather than a little excessively. It is often advisable, especially in assembly- or school-rooms and the like, to surround the stove with a sheet-

iron cylinder extending from the floor toward the ceiling and to bring in between this and the stove a supply of fresh air from without. This air becomes heated, and, passing out over the top of the cylinder or drum, gives a plentiful supply of convected heat and greatly improves the ventilation. (Figs. 28 and 30.) A suitable outlet must, of course, be provided.

Carbon monoxide and other gases are known to leak through cast iron when it is highly heated, so that stoves should not be allowed to become too hot. The production of carbon monoxide is most abundant soon after fresh fuel is added to the fire, and is evidenced by the characteristic blue flame above the coals. If at this time the escape of this gas into the outer air is prevented by the careless or accidental closing of a damper in the stove-pipe or chimney, it is prone to pass through the top and sides of the stove in the manner indicated, and to cause the serious and fatal results so often reported. Therefore it should not be possible to cut off completely the draught from any coal-burning stove, nor should it be materially lessened until combustion is well under way.

Other objections to stoves that are allowed to become too hot are the excessive dryness of the atmosphere which they cause and the unpleasant odor due to the scorching of floating organic substances that come in contact with the hot iron.

The fuel most commonly used in both grates and stoves is either wood or some kind of coal (bituminous, anthracite, or lignite); but gas or oil may often be advantageously and more satisfactorily employed instead of any of these, since the heat can be had from them practically instantaneously, can be closely regulated in quantity, and can be promptly checked when no longer desired, and since there is no production of dust or ashes in the room. The main objection to gas is that for large rooms or prolonged or continuous heating, it is usually more expensive than the other fuels; but this does not hold good for small rooms,

nor sometimes for isolated apartments or where warmth is needed only temporarily.

The ordinary kinds of gas-grates and gas-stoves, especially those which consume the gas incompletely, should all be constructed with flues to carry off directly the products of combustion, and this particularly when any large quantity of gas is used. Theoretically, when the gas is burned in a properly adjusted Bunsen or "atmospheric" burner, the only combustion-products will be carbon

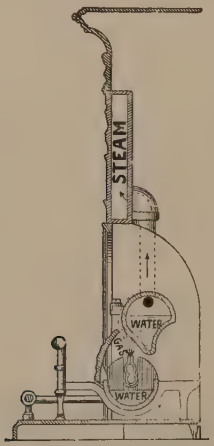


FIG. 31.—Section of Backus's portable steam radiator for use with gas.

dioxide and water, the former of which is rapidly diffused into the outer air, as has been shown, and is not likely to be harmful in any quantities thus produced, while the aqueous vapor is usually beneficial to the atmosphere rather than otherwise. However, it seems that in practice even these Bunsen burners may sometimes give to the air a disagreeable odor (said to be due to the formation of acetylene), and so occasionally need flue connections.

Of late years a new type of gas-heater has come into common use and which is apparently without risk because its heating elements are well-adjusted Bunsen burners, but which, nevertheless, may prove dangerous at times. These heaters utilize the flame of the Bunsen burners to make so-called "candles" or ornamental hollow tubes of asbestos or other minerals incandescent and thus "radiate" the heat to the apartment, and with no combustion products other than carbon monoxide and water. But Hayhurst and Dysart have found that when the flame is permitted to rise higher than three-fourths of the length of the "candle," carbon monoxide is given off in dangerous amounts and some serious accidents have occurred, some of them resulting fatally. Such accidents are especially likely to occur at night when the increased pressure in the mains tends to send the flame of the burner higher than the point to which it had been adjusted by the occupant of the room before retiring. Consequently, this type of heater should be used with caution until some safety appliance is devised that will obviate accidents of this kind. In fact it will be a safe rule to require that practically all gas heaters shall have adequate flue connections to carry off the combustion products, and that special care and watchfulness shall be given to any without such connections.

In this connection it may be interesting to describe one form of gas-heater which, so far as the writer knows, is unique. It is intended not only to consume perfectly the gas it uses, giving nothing to the air but carbon dioxide and water; but also to destroy by fire the impurities of the atmosphere of the room, thus doing away with chimneys or flues and the necessity of excessive ventilation. By a peculiar arrangement a continuous and large current of air is made to pass through the flame, thus consuming the impurities whether gaseous or solid. The heat of the burning gas is also used to convert a quantity of water into steam, which, by heating the containing chamber or coils of pipe and, in turn, the atmosphere surround-

ing these, warms many times the volume of air possible to heat by the flame alone. In addition, the humidity of the atmosphere is maintained by the evaporation of water from an open basin beneath the fire.

The ordinary openings of any room are amply sufficient to allow diffusion of the excess of carbon dioxide—one-half escaping in this way, according to Roscoe, within ninety minutes—and to permit the ingress of enough air to supply all the oxygen-needs of the inmates and of the fire itself. Experience and careful experiments seem to show that the claims of the inventor are well founded, and that the apparatus is healthful in its operation and produces no harmful effects even after continued use for several months. At any rate, there seems to be no reason why we may not purify the air by fire instead of by dilution and removal, the methods employed in the hitherto described systems of ventilation.

Oil-stoves are now used quite extensively, and, beside being portable, have the same advantages as gas-stoves, viz., that a considerable quantity of heat may be had quickly and just as long as it is desired, and at a fairly moderate cost. The combustion-products necessarily mix directly with the atmosphere of the room and, where reasonably perfect burning is had, doubtless consist of little else than carbon dioxide and water. One pound of oil, the hourly consumption of a rather large stove, will require about 150 cubic feet of air for its complete combustion, and will produce about 25 cubic feet of carbon dioxide.

"We do not think that the experience has yet been accumulated which would enable us to speak positively of the innocuousness of a considerable admixture of carbonic acid with the air we breathe; but the knowledge that in hundreds of cases oil-stoves are used for heating living-rooms and even bed-rooms, without apparent injury to the occupants, makes one feel fairly confident that the products of the complete combustion of hydrocarbons are not injurious when mixed with such an amount of air as

is sufficient to dilute to a proper degree the respiratory products. . . . Experiments show that, provided the combustion of the oil is complete and that the ventilation is sufficient for the ordinary effects of respiration, the use of oil-stoves for heating purposes may be advantageously employed in both day-rooms and sleeping-rooms. The efficacy of oil-stoves is increased by placing over them a diffuser or radiator, so as to prevent the heated products ascending direct to the ceiling; care needs also to be taken that only the better kinds of mineral oil are used; if inferior qualities of oil are burnt, perfect combustion is more difficult to obtain."[1]

The above remarks, as far as they apply to the healthful use of oil-stoves, may probably be used with equal justice in regard to gas-stoves, provided that with such dilution their products give no obviously harmful or disagreeable results.

CENTRALIZED HEATING.

The heating apparatus thus far described is such as we are accustomed to employ for warming the air of a single, or possibly of adjoining rooms. Where a whole dwelling or other large building is to be heated, it will usually be of advantage to do this from one point, and that not in any of the living apartments. In this way we shall have a centralization of fuel, both unburned and burning, and the ability to derive more heat from it; a lessening of the labor and attention bestowed on the fires; the obviation of much dust, dirt, and combustion-products in living-rooms, and, presumably, a more equable and satisfactory warming of the whole building. From such a central point the heat is distributed by hot air, hot water, or steam, or by hot air in combination with either of the other two.

Hot-air Furnaces.—Hot-air furnaces supply a large amount of convected but no radiant heat. There is a very

[1] Notter and Firth, p. 228.

prevalent opinion that they are not healthful, and that wherever possible they should be replaced by some other means of heating. But when properly constructed and cared for, a hot-air furnace of the ordinary kind and proper size is not only a good heater but also a powerful ventilating agent, for the large supply of air passing through it into the rooms above must in turn find an exit either through

FIG. 32.—Spear's hot-air furnace (without casing).

specially devised outlets or through the innumerable cracks and crevices around all doors and windows, and the ventilation will be accordingly.

One frequent source of trouble is too small a fire-box, giving insufficient heating surface and necessitating too rapid and too intense combustion of fuel. There should be a considerable expanse of surface, never too highly

heated, so that large volumes of air will be moderately warmed rather than small quantities overheated and "burned." Air too highly heated is very dry and offensive to the senses; also, by taking excessive moisture from

FIG. 33.—Hot-air furnace, showing cold-air inlet and hot-air flues. Only one of the lateral branches of the main inlet (*A*) above is shown.

the body through the skin and mucous membranes and by exciting glandular activity, it increases the liability to frequent "colds" and congestions. Moreover, a large quantity of air moderately warmed will perforce be car-

ried to *all* the rooms of the house, warming them equably and driving before it the air already there: whereas a much smaller volume, excessively heated by the same or even a greater amount of fuel, will make its way along the conduits of least resistance to a few favorably located rooms, overheating them while the rest of the house is unwarmed, and any satisfactory natural ventilation is thus prevented.

All joints in the furnace must be as nearly gas-tight as possible to prevent the combustion-products passing from the fire-box or smoke-flues into the air-chambers and thence into the rooms above.

The furnace should be located near the cold side of the house—that is, the side on which the prevailing cold winds impinge—for it is said to be as difficult to drive the air ten feet against the wind as forty or fifty feet with it. It may also be well, if the basement ceiling is low, to place the ash-pit below the level of the basement floor, in order to give sufficient slope to the air-ducts; but in every case the space beneath the furnace should be made impervious with cement or asphalt to prevent the drawing in of soil-air.

The air-supply should not be taken from the cellar, even though the latter be apparently clean and free from contamination with soil-air, but should come from a clean source out-of-doors, well above the ground-level and from the direction of the prevailing winds. The cold-air duct or ducts should be screened at the entrance to prevent the admission of refuse or vermin, should be arranged to permit of regular cleaning, should have a damper to regulate the supply of air, and should have a cross-section equivalent to at least two-thirds of the combined sectional areas of the hot-air flues leading from the furnace. The importance of a large air-inlet cannot be too strongly emphasized, for upon this feature may most depend the satisfactory action of the furnace. It may be desirable to provide for filtration of the air through coarse cloth or fine wire-gauze, especially if there be much dust in the incoming air.[1]

[1] See page 144.

To lessen friction, the hot-air flues or ducts should be preferably round or square and not too small or narrow in cross-section; and for the same reason they should be as direct in their course and as nearly vertical as possible. They should be covered from the furnace to the register-openings with asbestos or other non-conducting material to prevent the loss of heat that otherwise escapes from them into the cellar and between the partitions. Lastly, their register-openings into the rooms should not face the windows or prevailing winds, unless it be unavoidable, for if they do the passage of warm air into the rooms will often be almost, if not completely, checked.

The following table, from Coplin and Bevan, gives the proper size for hot-air flues and registers:

FIRST FLOOR.

Size of room in cubic feet.	Size of pipe.		Size of register.	
	If round.	If oblong.	If round.	If oblong.
Less than 1500 . .	7 inches	4 × 9 inches	9 inches	7 × 10 inches
1500 to 2000 . . .	8 "	4 × 12 "	10 "	8 × 10 "
2000 to 3000 . . .	9 "	4 × 16 "	12 "	8 × 12 "
3000 to 4000 . . .	10 "	4 × 18 "	12 "	9 × 14 "

Pipeless Heaters.—The realization that the principles of modern ventilation in ordinary dwellings does not require the introduction of a large supply of out-door air either to give a sufficiency of oxygen for the inmates or to dilute the carbon dioxide or volatile effluvia given off by them, has led to a modification of the ordinary hot-air furnace that is proving both satisfactory and economical for certain types of houses. It is evident that if a large quantity of cold air is continuously brought in from out-of-doors, passed through the heater to be warmed and then, after traversing the various rooms of the house, is almost immediately pushed out by the oncoming supply,

there must be a considerable loss of heat that has served no good purpose if the extra air that carried it was not needed by the inmates, with a consequent wastage of the fuel that supplied it. In other words, it is wasteful to warm more cold air from out-of-doors than is actually necessary to keep the in-door atmosphere in a healthful and comfortable condition, and economy will be served if means can be devised whereby no more than the needed amount of cold air shall be brought in, warmed and kept circulating throughout the house.

The so-called pipeless furnace prevents much of this waste by an arrangement that permits the partially cooled air from the rooms above to be again drawn through the heater and repeatedly rewarmed. This is accomplished by doing away with most, if not all, of the flues leading from the heater to separate rooms above and supplanting them by one large warm-air conduit and register opening in the floor of the hall or room directly above the furnace, this register being encircled by another concentric one through which the partially cooled air of the house drains back into the furnace to be again warmed and sent up through the central register with a new supply of heat. It may be advisable in certain cases to provide one or more separate flues to distant or unfavorably located rooms, but experience shows that if the inner doors be kept open there is a very equable circulation of the warmed air throughout the ordinary dwelling, and it is obvious that there must be a very considerable saving of heat by this method, especially in cold weather when it would be necessary to consume a large amount of fuel in the ordinary furnace to warm to a satisfactory degree the continuous stream of cold air from without.

There will usually be a sufficient change and renewal of air for all demands of health and comfort, not only through the customary and frequent opening of doors and windows throughout the day but also by way of the many minor openings about doors, windows, floors, etc., and any lack of enough fresh air to keep the in-door atmosphere in

good condition can be quickly supplied by temporarily opening a window or two. Of course, just as in the use of the ordinary hot-air furnace or any other type of heater, sufficient water should be supplied for evaporation to maintain a proper degree of humidity in the house-air.

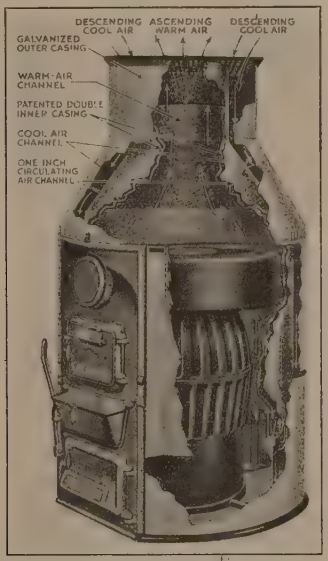


FIG. 34.—Sectional view of a pipeless heater. The one register is placed in the floor directly over the heater and connected with it. (Courtesy of Caloric Furnace Co.)

For dwellings in which the ordinary furnace is already installed, a similar advantage and economy may be had by placing a large register in the floor of the hall or other convenient room of the first story and connecting this by means of a large conduit with the lower part of the furnace. In cold weather it is then possible to cut off by means of a damper the supply through the regular inlet from

out-of-doors and to draw the partially cooled air of the house through the new inlet and thus maintain a continuous circulation of rewarmed air with a considerable saving of fuel and, usually, increased comfort.

FIG. 35. Illustration showing method of heating by a pipeless furnace and elimination of the usual warm-air flues to separate rooms. (Courtesy of Caloric Furnace Co.)

The principle of this method of rewarming and circulating air is illustrated in Fig. 38, which shows it as applied to indirect heating by steam or hot water, and by Fig. 35.

Where this method of heating is used it will be advantageous to have removable screens placed beneath the register of the conduit leading to the furnace in order to collect and filter out the dust from the air of the house and any dirt from the floor, and also to secure articles that may accidentally be dropped through the register.

Economy will be subserved in most cases by taking care to burn the fuel in hot-air furnaces quite slowly, since in this way larger quantities of air are warmed and more satisfactorily, and there is also less waste of heat through the smoke-flues and up the chimney. Moreover, it is the experience of the writer that by working the furnace in this way at low pressure, so to speak, the air from it will be less likely to become too dry, nor will it need the addition of so much moisture, something essentially necessary and yet most often neglected where comparatively little air is excessively heated.

The amount of water to be added also depends upon the humidity and temperature of the out-door atmosphere. When the latter is but little, if at all, below the freezing-point and is almost saturated, and when the in-door air is but moderately warmed, as suggested, the lack of added moisture may scarcely be noticed; while if the air without be at the same time dry and very cold, its actual content of water will be very little, and much added moisture will be needed to make it either comfortable or healthful, even though warmed to only a moderate degree.[1]

"Concerning the need of insuring a normal amount of moisture in the air of heated buildings, there is more or less difference of opinion, but the weight of evidence from a medical stand-point, and from our own sensations, points

[1] Most modern furnaces have a water-pan from which evaporation may take place into the warmed air, but the filling of this, when left to servants, is so often neglected that connection with the water-supply of the house by means of a float-valve or automatic cut-off would better serve to secure a constant supply. Even then, these water-pans as ordinarily constructed are probably inadequate, especially in cold climates, to maintain the degree of humidity desired, and additional moisture should be provided from other sources, if possible.

to the advisability of introducing an amount of moisture sufficient to bring the relative humidity of the air to 50 or 55 per cent. . . . Air at 25° F., saturated with moisture and then heated to 70°, would need over a half-pint of water in every thousand cubic feet to give it a humidity of 65 per cent., and this is far in excess of the capacity of the ordinary water-pan of the furnace, as is seen when we reckon what half a pint per thousand cubic feet means in the course of a day."[1]

Some recent tests by H. M. Smith, of Brooklyn, show that a relative humidity above 50 per cent. and a tempera-

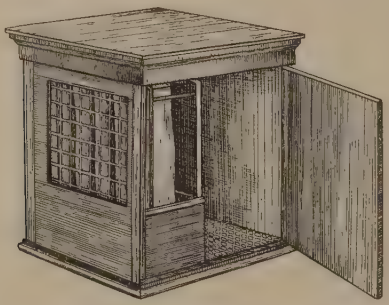


FIG. 36.—Humidifier. The cotton wicking shown absorbs water from a reservoir below. (Harrington.)

ture of about 65° F. is most healthful and comfortable. "With a temperature of 72 or 74 degrees and a relative humidity of 30 per cent. as compared with a room at 65 to 68 degrees and a relative humidity of about 60 per cent., the latter seemed the warmer and more comfortable." On the other hand, Ingersoll[2] believes that in very cold climates the ideal in-door humidity for a temperature of about 70° is from 40 to 45 per cent., and that when above 50 per cent. the condensation in cold weather is unbearable.

[1] Harrington, pp. 420 and 421.
[2] Journal of Home Economics, April, 1915.

Prof. Wilson, of Milwaukee, says further: "About 25 per cent. of the cost of heating is expended in raising the temperature from 60 to 70 degrees; so if we can keep comfortable at a temperature of 65 degrees, we shall have saved at least 12.5 per cent. of the total cost of heating."

Hot-water and Steam-heating.—When it is necessary to carry heat for a considerable distance or to warm large buildings or blocks of buildings from a central point, it will be better and more economical to employ hot water or steam as the heat-transmitting agent, on account of the high specific heat of the former and the great amount of latent heat held by the latter. "It is uneconomical to convey heated air any long distance, as the amount of heat conveyed per cubic foot of air raised to any practical temperature is so small and so easily lost in transit. On this account Morin considers the availability (of hot-air furnaces) to be limited to a horizontal range of 40 to 45 feet from the heating apparatus."[1]

An equal quantity of heat, viz., 1 thermal unit, is required to raise 1 pound of water or 50 cubic feet of air 1 degree F., and accordingly water will carry more than four (4.21) times as much heat as an equal weight of air at the same temperature. "Further, a greater effect is produced when water, in the form of steam, is made the carrier of heat, because 1 pound of water vapor at 100° C. (212° F.) will, in condensing to form boiling water, give off sufficient heat to raise the temperature of 5.36 pounds of water (or $4.21 \times 5.36 = 22.5$ pounds of air) from 0° to 100° C. (32° to 212° F.)."[2]

Hot-water heating may be by either the low-pressure or the high-pressure system. In the former, large pipes are used, and, the system being open to the air at its highest point, the temperature of the water can never be much above 212° F. at any part of the system. The water circulates comparatively slowly, but owing to the large volume, conveys much heat from the furnace to the places where

[1] Stevenson and Murphy, vol. i, p. 117.
[2] Notter and Firth, Treatise on Hygiene, p. 231.

it is needed. The high-pressure system employs small but very strong pipes, the water being completely enclosed from the outer air, wherefore it attains a high temperature and circulates rapidly. The necessary expansion is provided for by larger pipes partly filled with air at the top of the circuit. The maximum temperature is regulated by the proportion of pipe, usually one-tenth, exposed to the fire. Either of the hot-water systems, but especially the low-pressure one, requires careful planning and setting to maintain evenness of circulation; and when the latter is complicated, as by many radiators at various levels, or where a number of circulations have to be supplied from the same boiler, it may be very difficult to maintain an even head and an equable distribution of heat in all. "If properly constructed and the heating planned for when the house-plans are made, this hot-water system is probably the most economical, both in fuel used and repairs demanded."[1]

Steam-heating methods are usually quite satisfactory, not only because of the large quantity of heat carried, but also since a rapid circulation is readily maintained even under adverse circumstances. The size of pipe used will depend on the extent of the distribution, but the caliber of the radiator should always be considerably larger than that of the supply-pipes in order to favor condensation and the consequent liberation of latent heat, and every facility should be provided for the speedy return of the condensed vapor to the boiler. Care must also be taken to prevent the condensation occurring in such a way as to cause obstruction to the flow of the steam and the disagreeable thumping and noise that result.

Safety-valves on steam boilers lessen the risk of explosions, and automatic thermo-regulators make it possible to maintain a practically even temperature throughout the house or building at all times. But there must be some arrangement for supplying additional moisture to

[1] Coplin and Bevan, p. 325.

the warmed air, just as with hot-air furnaces, for, contrary to the opinion of many, neither the steam nor hot-water systems increase the atmospheric humidity.

An excellent method of combined ventilation and heating is to use the plenum system, and to warm or "temper" the incoming air, either before or after it passes through the driving fan, to a temperature somewhat below that desired in the rooms, in which steam or hot-water radiators are suitably located. The air will then pass from the inlets more or less directly to the radiators and be additionally warmed by them before rising above the lower levels of the room. In this way the regulation of heat and the circulation and distribution of the fresh air are much improved, and there is less likelihood of the latter going directly from inlets to outlets.

With either steam-heating or hot-water heating the direct, the indirect, or the direct-indirect method of radiation may be used. Of these, the *direct* method—that is, where the radiators are placed in the rooms to be warmed—is most commonly employed in dwellings and other buildings of moderate size; but it is open to the objections that in itself it does not bring about a change of air, that the necessary inlets and outlets for the latter are rarely provided, and that when present they are independent of the heating system of the house. Of course, these objections are wanting when the direct is combined with the indirect method, or when a plentiful supply of pure air is brought from without and is warmed by being made to pass through the radiators (either open or enclosed in boxing) before diffusing through the room.

In the *indirect* method the radiators are placed outside of the room in suitable and convenient enclosures, into which fresh air is brought from out-of-doors, and from which the warmed air is conveyed by suitable conduits to the respective rooms above. The *direct-indirect* method locates the radiators in the room, but encloses them and provides inlets to the boxing from without, so that the entering air must pass over the heating surface and be

warmed before entering the room. If properly arranged, both the indirect and the direct-indirect methods should furnish good and ample ventilation, the incoming warm air pushing the used air of the room ahead of it through the various openings in the walls of the room.

FIG. 37.—Indirect radiation.[1]

FIG. 38.—This illustration shows a good method for incasing indirect radiation and also suggests a simple way to secure rotary circulation of the air in the room when it becomes desirable to shut off the out-door supply. The registers in the floor, however, are not advisable, as they readily collect dust and dirt.

[1] Figs. 37, 38, and 39 are used by courtesy of The American Radiator Co.

To determine the amount of radiating surface needed for any room, we must multiply the volume of air to be heated per hour by the difference between its temperature in degrees Fahrenheit before and after warming, and divide this product by 50, the quantity of air in cubic feet raised 1 degree F. by 1 thermal unit. This will give the

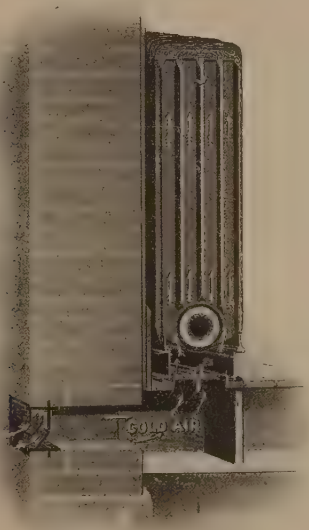


FIG. 39.—Direct-indirect radiation.

number of heat-units required to warm the air. Then this quotient must be divided by the difference between the temperature of the radiating surface and that of the air when finally warmed multiplied by 1.75—the number of thermal units given off per hour by 1 square foot of hot-water or steam-pipe for each Fahrenheit degree of

heat it loses. This will give the area of hot-water or steam-pipe required to warm the given volume of air. Thus, to warm 6000 cubic feet of air per hour from 20° to 70° F. will require

$$\frac{6000 \times (70 - 20)}{50} = 6000 \text{ heat-units,}$$

and if the temperature of the surface of the radiator be 200° F.,

$$\frac{6000}{(200° - 70°) \times 1.75} = 26.37 \text{ square feet, which}$$

will be the area of radiating surface required. To this must be added at least one-half square foot for each square foot of window-glass and for each square yard of outer wall exposed.

CHAPTER VII.

WATER.

Next to air, water is the most important of all substances necessary to human life. While it has been often demonstrated that man may do without food for a considerable length of time, even for several weeks, he can probably not survive much more than ten days without water. Not only must one have sufficient to supply the internal wants of the body and to replace that lost by excretion, evaporation and respiration, but from a sanitary point of view a plentiful supply is also needed to maintain cleanliness of bodies, clothing and dwellings, and oftentimes to remove sewage, excreta, etc., from the vicinity of inhabited places. The care of furnishing water in abundance and of maintaining its purity is therefore entirely within the domain of the physician and the sanitarian.

Before inquiring into the sources whence we obtain the water that we use, it will be well to know what amount is required by the body for its daily needs and how much for other necessary purposes, so that we may be able to judge not only whether a given source furnishes pure water, but also whether it gives a sufficient supply of it.

The average adult should take from 70 to 100 fluid-ounces per day for nutrition and internal needs of the body alone—about one-third of this being a component part of the food and the rest being taken in as drink. The writer is of the opinion that the average person does not imbibe enough water for the most healthful action of his tissues and organs. Certain it is that in most cases the plentiful use of a good drinking-water not only greatly favors the body metabolism, but also materially assists in

the flushing out and carrying away of the various wastes and excreta of the system.

In addition to this we must supply a sufficiency for cooking and for washing the food, body, clothing, household utensils and parts of the house itself, and to remove the household waste and sewage through the drains and sewers provided for that purpose. Cleanliness is an essential requisite for the preservation of health, and cleanly habits should be inculcated among all classes of people and every facility provided for removing filth of all kinds from persons, clothes and dwellings. This, of course, cannot be done without an abundant supply of water.

Experience shows that about 25 gallons per head per day should be furnished for the above purposes, and as the quantity used by domestic animals, manufacturing establishments, municipal needs, etc., must be added to this, 50 gallons or even more per capita should be the daily quota for a community wherever it is at all possible to secure it. And though a supply that permits of excessive waste may be inadvisable and expensive, both in its provision and on account of increasing the cost of carrying it away after use, it is always better to have too much than too little, and the disadvantages of too scanty an amount are much greater than those of one too large.

It should be stated, however, that most foreign cities are supplied with much less water per capita than is apparently needed by the municipalities of this country, and yet they seem to have an abundance for all necessary purposes and the requirements of public health. For instance, London has an average daily supply of about two-thirds that of Philadelphia with one-third the number of inhabitants; while Berlin, with about the same population as Philadelphia, had in 1905 an average daily supply of filtered water of only 22 gallons per head, all of which was sold to consumers by meter, but to which must be added considerably more that was from wells and other sources and was exclusively used for manufacturing purposes, running machinery, etc. Undoubtedly the quan-

tity wasted in many of the cities in this country is excessive, and the cost of supplying that part of the total quota would go a long way toward improving and rendering pure and safe the remaining part that is absolutely needed. Whether the compulsory use of water-meters is the best way of bringing about an improvement in this respect remains to be determined; but it is also a question whether our larger cities, with rapidly increasing populations, can afford to continue to expend the money necessary to purify the enormous and increasing quantities of water daily supplied to their respective consumers. With the observance of due care and conservation, a daily average of 100 gallons per capita would probably be found to be a reasonable maximum for almost any community.

As only a small portion of the quantity indicated above is required for the internal needs of the body, it has been suggested that two kinds of water be furnished to each dwelling—one for drinking and cooking purposes and for the washing of the body, to which especial attention as to purity should be given; and another kind for all other purposes, its composition and purity being disregarded, excepting possibly as concerns the hardness. This would enable the authorities to furnish a water purer than usual for those needs wherein purity is of the greatest importance, and would obviate the necessity of furnishing pure water abundantly for *all* purposes; but the plan would necessitate a double set of reservoirs, mains, distributing apparatus, etc., thus materially increasing the cost; and there would always be present the danger of the careless or ignorant using the impure water for bodily needs, thus increasing the risks and bad results that we wish to avoid. Therefore it will be best to have but one supply, and this as pure and abundant as money and the ablest sanitary skill can make it.

As to the question of supply through meters, it may be added that the suggestion has been made that the regular charge for water begin only after a certain specified amount per month per capita or per household has been furnished

free or at the lowest possible cost, thus doing away with the objection that those who need the water most for personal and sanitary uses would be tempted to economize too much if they had to pay what they considered a high price for all they consumed. To compensate for this it might be wise to arrange a sliding or increasing price scale for larger quantities. Whether a city could afford to do this, would have to be carefully considered, and would probably depend largely upon local conditions.

Another method is "to assess every owner of premises where water is used (and measured by meter) a certain moderate, but fixed, sum yearly, even though water used at the regular rate per thousand gallons does not call for so much charge." This initial sum should be considerably less than the rate necessary under the old method, and in itself is an inducement to the introduction and use of meters. Any water used in excess of the volume represented by this primary charge is, of course, to be paid for at the regular meter rate.

Experience shows that meters greatly reduce the total consumption of water, since it is to the direct advantage of each consumer to check reckless waste on his own premises, which duty is otherwise neglected because it does not affect the yearly charge and cost of water to him. Meters, wherever used, seem to have materially reduced both the cost of water to the consumer and the cost of supplying it on the part of the city or other owners of the water-works, and, so far as the writer knows, no city or community that has once installed a meter system has discontinued their use.

SOURCES OF WATER.

Practically, all drinking-water has at some time or other fallen upon the earth from the atmosphere in the form of rain, hail, snow, or dew; but when we speak of its source we have reference rather to the immediate place or locality from which we collect it for use. The

rain on reaching the earth is disposed of in three ways: part at once evaporates and goes back to the atmosphere,

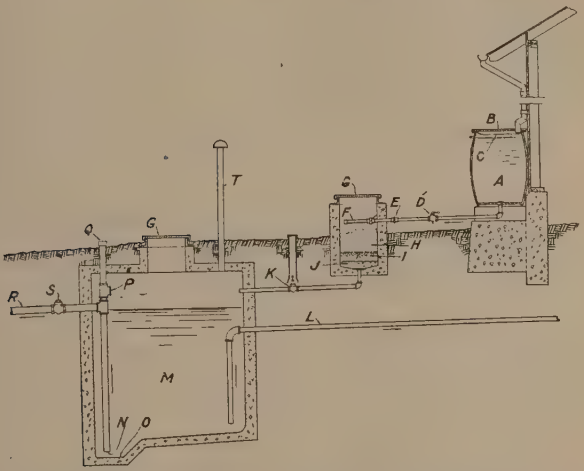


FIG. 40.—Cistern and filter installation. Approximate cost, $150. *A*, Hogshead or large tank; *B*, tight-cover; *C*, wire screen; *D*, ¾-inch 2-way rain cock; *E*, ¾-inch union; *F*, ¾-inch brass or galvanized pipe, perforated; *G*, tight overhanging cover; filter box may be wood, iron, brick, concrete, or 4 feet of large-size vitrified pipe; *H*, 24-inch layer fine sand; *I*, 6-inch layer well-burned wood charcoal size of wheat grains; *J*, 2-inch layer of gravel size of a small pea to give support and drainage; *K*, ¾-inch 2-way rain cock with 1 branch piped to waste; *L*, suction pipe; *M*, cistern, side walls 6 to 10 inches thick; *N*, 1-inch overflow; *O*, sump or catch basin; *P*, emergency overflow; *Q*, screw cap (remove cap and attach hand pump when cleaning cistern); *R*, waste pipe; *S*, swing check valve; *T*, screened ventilator. When starting operation, waste the first water filtered; throttle cocks *D* and *K* to give the desired low rate of filtration; maintain water level above sand layer, thus protecting the surface film of mud. (Water System for Farm Homes, U. S. Department of Agriculture, *Farmers' Bulletin*, p. 941.)

part flows off according to the slope of the ground and collects in pools and streams, and part sinks into the soil. The ratio which these three portions bear to one

another depends on the time, place, character of soil, amount of rainfall, etc. Consequently, we may classify the sources of potable waters—as Leffmann does—as follows: *rain-water*, collected immediately as it falls in the form of rain, dew, snow, etc.; *surface-water*, collected in ponds, lakes, streams, etc., and in free contact with the air; *subsoil-* or *ground-water*, derived mainly from the rain- or surface-water of the district, but which percolates and flows through the subsoil and is therefore not exposed directly to the atmosphere; *deep-* or *artesian-water*, which is separated from the ground-water of the district by one or more practically impermeable strata, and which accumulates at a considerable depth below the surface. Springs are the result of the out-cropping of water-bearing strata below the level of the water-line in them, and furnish either subsoil- or artesian-water, according to the kind contained in the respective strata.

Rain-water is theoretically the purest at our command, but in reality it takes up many impurities from the air in its fall, especially in the neighborhood of human habitations and communities, and by the time it reaches the earth contains ammonia, nitrous and nitric acids, and, in towns, sulphurous acid, soot, many bacteria and other microscopic plants. Moreover, and especially after continued dry weather, the collecting surface upon which it falls is apt to be covered with dust and impurities of all kinds, which, being taken up by the rain-water, tend to make it unfit for use. But if there be some arrangement for turning aside the first portion of the rain, it containing the most of the impurities, and if the remainder be filtered and stored in proper receptacles, the water may be of excellent quality.

The main objection, however, to the sole use of rain-water is that dependence is placed upon a very uncertain source, and one which is especially apt to fail when an increased supply is most needed. The average rainfall in Philadelphia is about 39 inches per year; in very wet years it is about one-third more, and in very dry years

about one-third less than the annual average. Each inch of rainfall gives 4.67 gallons per square yard of area on which it falls, equivalent to 22,617 gallons per acre. Allowing 60 square feet of collecting surface per head and estimating the loss by evaporation, etc., at 20 per cent., an annual rainfall of 30 inches would give only about 2 gallons per head per day, or just about sufficient for drinking and cooking purposes, and none for the other needs of the household.

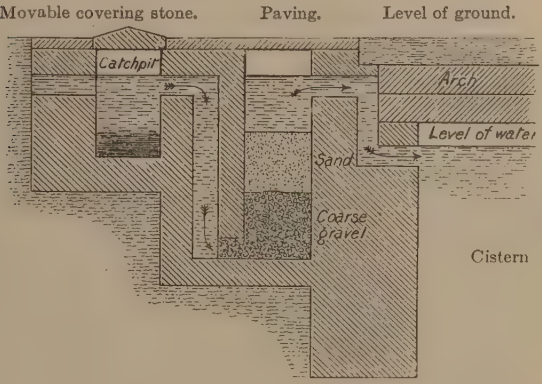


FIG. 41.—A simple filter for rain-water. (Notter and Firth.)[1]

Rain-water may be collected from roofs or from a plot of ground paved for the purpose with slate or cement, and be led by proper conduits to a cistern. It should be filtered before passing into the cistern (Figs. 40, 41 and 42), while the cistern itself should be such as to give no unpleasant taste or injurious substance to the water, should be so situated that it will receive no rubbish or impurities and that the

[1] Fig. 41 illustrates a filter for an underground cistern. One of similar construction can be readily made for cisterns above ground, the latter being always preferable.

water may be kept cool, and should be cleaned regularly and sufficiently often to keep the water sweet and wholesome. As rain-water contains considerable carbon dioxide and other gases, its solvent powers are increased, and cisterns should not be lined with lead, copper, zinc, or iron, lest these metals be taken up by the water and produce harmful results. These remarks do not apply to the so-called rustless iron now much used; but galvanized iron should not be used, as it may give up zinc to the water.

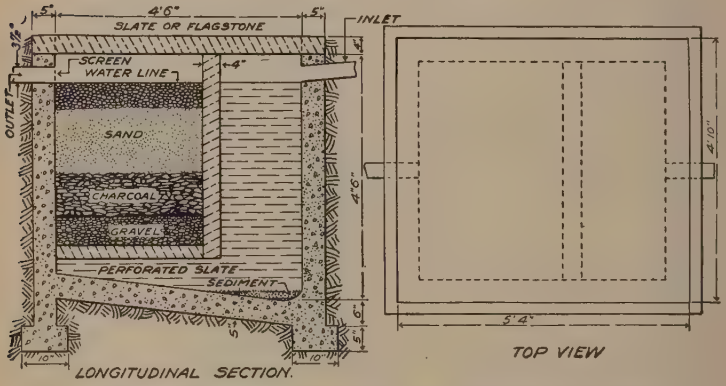


FIG. 42.—Cistern filter of concrete and stone. (Bulletin No. 57 of the U. S. Department of Agriculture.)

Cement should also be used in lining brick or stone cisterns instead of ordinary mortar, as the latter may add lime to the water and render it hard.

Underground cisterns for storing rain-water should be avoided where possible, since they are liable to soil-air or sewage contamination unless absolutely air- and water-tight. Nor should the overflow pipe from a cistern open into a soil-pipe or sewer-pipe or drain, but always into the open air, since water is very prone to absorb the various gases with which it comes in contact and the sewer-

air may readily contaminate the entire contents of the cistern.

Rain-water is especially valuable for cooking and washing on account of its softness, water being called "hard" when it contains an excess of the salts of calcium or magnesium in solution. Hardness due to the presence of calcium bicarbonate is said to be *temporary*, because it disappears when the water is boiled, one molecule of carbon dioxide being driven off by the heat and leaving the more insoluble calcium carbonate behind. Hardness due to many of the other salts of calcium and magnesium is called *permanent*, because it is not removed by boiling. In cooking with water temporarily hard the chalk is precipitated upon the sides and bottom of the vessel, and, being a non-conductor, prevents the passage of heat and thus wastes fuel.

Hard water may also prevent the proper softening of certain foods, such as peas and beans, in cooking. In washing and laundry work the calcium and magnesium salts unite with the fatty acids of the soap and prevent the formation of a lather; for instance, one grain of chalk destroys the efficiency of about eight grains of soap. As we do not call a water hard unless it contains more than ten grains of chalk or its equivalent per gallon, and as rain-water rarely contains more than one-half grain per gallon, it is easily understood why the latter is so valuable in the kitchen and laundry.

Surface-waters.—A water-supply taken from rivers or smaller streams not polluted by the refuse and sewage from towns, factories, or cultivated farm-lands higher up the stream, may be fairly pure and safe to use. The best water of this kind will be from hilly and uninhabited, uncultivated tracts, with many small streams fed by constant springs and uniting to form rapid creeks and rivers. Such water may be tinged slightly with vegetable or mineral matters, but in general such coloration is harmless. For storage, dams may be thrown across convenient valleys, thus impounding the water and at the same time exposing it to the oxidizing and aërating influence

of the atmosphere and allowing the solid impurities to settle to the bottom. Small lakes or ponds may be utilized to add to supplies of this kind, provided they be not stagnant nor have much decaying matter along their banks.

On the other hand, water from a stream which has received the sewage from a village or town of any considerable size, or the refuse of factories, or the drainage from large tracts of cultivated land, should be considered as at least suspicious. River-waters are generally hard and may contain any of the minerals in the soils which they drain or over which they pass; but the great danger is from impurities of animal origin poured into them along their course.

It is not safe to depend altogether on the self-purification of sewage-contaminated rivers, as was formerly done, though a considerable portion of the sewage and filth undoubtedly is removed, part by oxidation by the air in the water, especially in streams flowing over dams, rapids, etc.; part by subsidence or deposition along the banks; part by fish and animalculæ, and much by the myriads of saprophytic bacteria which such waters contain. If no additional pollution is added, what is left unchanged by the above purifying agencies is still further diluted by the supplies of pure water that every stream receives from springs along its banks and in its bed and from tributary streamlets, so that, though the water may never be so pure as it was originally, it may possibly become or, by proper filtration or other treatment, be made a safe and usable water. But where the proportion of filth exceeds a certain percentage, and especially where sewage is being constantly added, the contained oxygen is rapidly used up and oxidation ceases, fish and animalculæ cannot live in the water for lack of sufficient oxygen, and though the heavier and larger particles of the sewage sink to the bottom or stick to the sides, they are stirred up and set in motion by any increase in the velocity of the current. The only remaining agents active in the destruction of the

foul matter are the bacteria, but in themselves they are often insufficient for the task, and the water thus polluted is unsafe for use.[1]

The greatest danger from sewage contamination, however, is that it may at any time add to the water the germs of infectious disease, which multiplying rapidly and not being surely removed or destroyed by the ordinary agents or methods of water-purification, greatly increase the risks to health. It often fortunately happens that, owing to the hostility of the saprophytic bacteria of the water, or to the presence of certain chemical substances, or

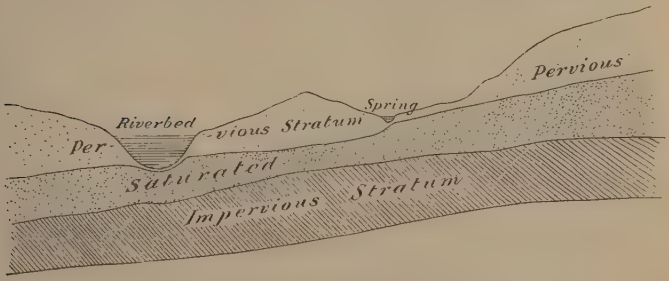


FIG. 43.—Outcropping of water-table. (Harrington.)

to other unfavorable conditions, as of temperature and the like, these pathogenic organisms do not multiply so rapidly as they otherwise would, and are therefore not plentiful enough to do much harm. But, as it never can be certainly told when a water so contaminated becomes safe for use again, and as the population of most towns and their consequent sewage production are constantly increasing,

[1] According to the report of the Rivers Pollution Commission some years ago, no stream in England is of sufficient length to purify itself satisfactorily of the sewage contamination it is liable to receive. On the other hand, according to a report (April, 1903) of the Commissioner of Health of Chicago, very careful and extensive investigation shows that the large quantity of sewage from that city discharged into the Illinois River has entirely disappeared long before the latter empties into the Mississippi at a point over 250 miles from Chicago.

while the quantity of water in the receiving streams remains about the same or is diminishing from year to year, the use of such water should be avoided if possible; or, if it must be used, it should be purified and made reasonably safe by the most scientific and efficient means and methods available.

Water from large fresh-water lakes will be of the best quality, provided it be taken from a point sufficiently distant from the shore to escape all danger of sewage contamination. Chicago apparently lowered the mortality percentage from typhoid fever from 7.2 in 1891 to an average of 2.1 for the decade 1896–1905, and to 1.1 for 1908, by preventing as far as possible the discharge of

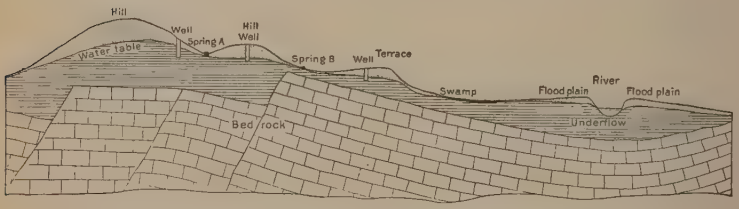


FIG. 44.—Section showing relation of water table to surface irregularities. (U. S. Geological Survey, Water-supply Paper 255.)

sewage into Lake Michigan and by taking the water-supply from the lake at a minimum distance of two miles instead of 1400 feet from shore as formerly.[1] Water from small lakes or ponds, and even from storage reservoirs, may become offensive to taste and smell through the growth in them of minute vegetable organisms, such as the algæ, though it is not known that these are prejudicial to health.

Subsoil- or Ground-waters.—Ordinarily, water loses much organic matter as it percolates through the soil, but takes up considerable carbon dioxide from the soil-air,

[1] One water-supply extends only 3300 feet out into the lake, but this supplies not more than 12,500 persons in the extreme north end of the city, and the water is sand-filtered.

which increases its solvent powers so that it may also dissolve some of the mineral constituents of the soil through which it passes. When these mineral substances become so great in amount as to give the water a decided taste or medicinal properties, we call it a mineral water; but when the inorganic matter does not render it objectionable to the taste or too hard, the water, whether subsoil or artesian, will usually be quite safe and usable in so far as the mineral matters are concerned.

Attention has already been called to the pollution of the soil. How, then, can the water in passing through it lose its organic contents and become pure? Partly by mechanical filtration, but mainly through the combined action of the saprophytic soil-bacteria and the oxygen of the soil-air, which rapidly convert the organic impurities, both suspended and dissolved, into simpler and harmless end-products. The substances of vegetable nature are ultimately resolved by these agencies into carbon dioxide, water, etc., while those of animal origin and containing nitrogen give rise to the various ammonia compounds, or may be further oxidized into nitrous and nitric acids and their salts, all entirely harmless in the proportions in which they are found in the percolating ground-water, but all of great value as nutrients for the higher plant-life of the soil.

The rate of percolation has much to do with the completeness and perfection of this action, for ample time must be had for the organic decompositions to occur. Therefore, anything that retards the downward flow of water favors its purification, and anything that increases its movement decidedly affects for the worse its ultimate quality and character.

The importance of this biological soil action can scarcely be overestimated, and the student should endeavor to appreciate not only the bearing which it has in the great scheme of nature's adaptation of means to ends, but also the importance of our utilization of it in the artificial purification of our environment and in the disposal of

waste matters. We must understand, however, that for every soil only a definite amount of work can be accomplished by the agencies mentioned and under the conditions existing at any given time. In other words, there is here also a *limit of permissible impurity*, and if

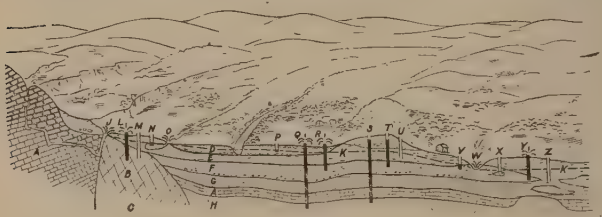


FIG. 45.—Diagram showing how wells and springs may be affected by geologic conditions, surface elevation and by differences in location and depth. *A*, limestone showing both small and large passageways; *B*, jointed crystalline rock; *C*, solid crystalline rock; *D*, alluvial soil; *E*, comparatively impervious stratum, as clay; *F*, stratum composed of sand, gravel, bowlders, clay and mixtures of them; *G*, comparatively impervious stratum, as clay or hardpan; *H*, porous sandstone; *J*, fissure spring (may be contaminated easily by campers or others); *K*, water table or line below which ground is saturated; *L*, flowing well (strikes joints carrying water); *M*, non-flowing well (strikes no joints); *N*, shallow well (strikes a pocket of sand); *O*, seepage spring (yield small and perhaps during wet weather only); *P*, shallow and poor well; *Q*, artesian well (strong flow); *R*, artesian well (bottom in sand, flow moderate); *S*, *T*, non-flowing artesian wells (head insufficient to force water to the surface of the high ground); *U*, well in clay (no yield); *V*, shallow well in sand; *W*, hillside spring (both *V* and *W* are liable to contamination from the house wastes above); *X*, shallow and dry well (bottom in clay and against a bowlder); *Y*, flowing well (bottom in sand); *Z*, dry well (same depth as well *Y* but sunk where the water-bearing bed thins out). (Water Systems for Farm Homes, U. S. Department of Agriculture, *Farmers' Bulletin*, p. 941.)

this limit is exceeded, the conditions become unnatural, the bacterial and chemical action is inadequate, and the descending water is not thoroughly purified as it percolates through the overcharged soil.

The subsoil-water slowly sinks through the ground until at some level or other it reaches an impermeable stratum,

where it is retained in natural basins or escapes at some outcropping of the stratum below the water-level, thus forming a spring. (Figs. 43, 44, and 46). The level of the water in these undergound reservoirs is constantly changing according to the season, rainfall, discharge from springs, etc., though ordinarily the variation for any given place differs little from year to year. It is from wells sunk to these water-bearing strata and from springs that water is obtained for the majority of people who do not live in towns or cities supplied by water-works (Fig. 45). These underground bodies of water are in constant motion toward one or more outlets at more or less distant points, but the

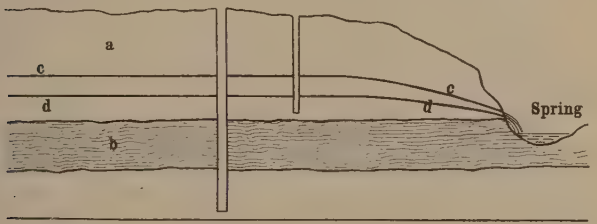


FIG. 46.—Representing the difference between shallow and deep wells, and between the high-water and low-water level of the ground-water; *a*, soil and gravel; *b*, clay or rock, *c*, *c*, high-water, and *d*, *d*, low-water level.

currents are usually quite sluggish owing to the friction and capillary force of the particles of soil through which they pass. For the same reasons the surface of the water is not horizontal but curved, the curve being sharpest near the outlet, and the difference in level between high and low water is least near the outlet; also, the higher the level the greater the fall to the outlet and the greater the discharge. (Fig. 46.)

The outflow from most continuously flowing springs represents the percolation through and drainage of such a comparatively large area that it is not probable that any considerable proportion of this area will be exces-

sively polluted, nor that the percolate from any and all overpolluted parts of it will be so concentrated and charged with harmful impurities that the thoroughly purified water from the remainder of the area will not be sufficient to dilute it sufficiently to eliminate all danger to health from its use. Consequently, springs are to be ranked among the best and safest sources of natural waters, and general experience sustains the judgment.

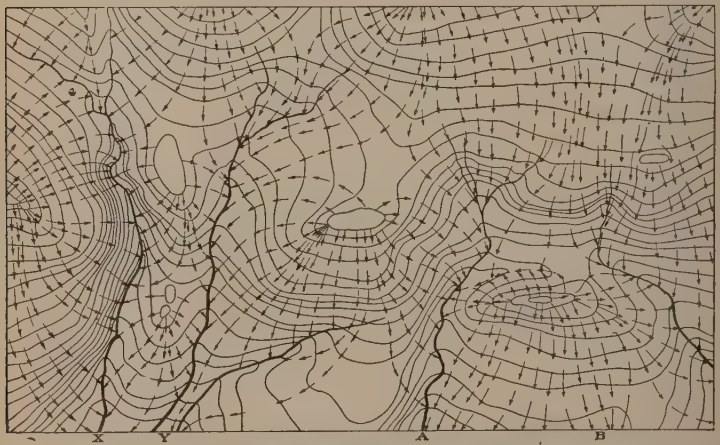


FIG. 47.—Map showing position of water-table by contours (continuous lines), lines of motion of ground-water (arrows), and surface-streams. (U. S. Geological Survey, Water-supply Paper 255.)

But the remarks regarding the purity of spring-water do not hold good for water from ordinary shallow wells—provided they do not pass through an impermeable stratum—or from springs where the water passes almost directly from surface to outlet, for in both cases the filtering action of the soil and the removal of organic matter by the prolonged action of the saprophytic bacteria are likely to be incomplete and imperfect. Likewise,

water from springs that drain a limited and extensively polluted area may be seriously contaminated, and unsafe to use.

Especially about human dwellings, where wells are commonly located for the sake of convenience, are filth and pollution likely to be carried into the water, for sewage and dirt of almost every kind accumulate in constantly increasing quantity in the soil about a house, and always tend to exceed the limit of permissible impurity. There is also the ever-present danger of the water receiving the specific germs of disease from the human wastes of the household, no matter in what condition the surrounding soil may be. In this connection it is well to call attention to the fact that the visit of a transient and possibly unsuspected typhoid- or other "carrier" to a house or locality may be the source of an infection through the well-water and thus serve to explain the occurrence of a given disease where it has not occurred for a long time previously, if ever.

Owing to the lessening of lateral resistance the surface-water passes rapidly and almost directly into the well (unless the wall of the latter be made water-tight to almost the full depth), and may carry with it solutions of all the impurities polluting the soil about the mouth; and as wells drain a very considerable area—Parkes says one, in ordinary soils, whose radius is equal to four times the depth of the well—there are few wells about which such an area is not subject to dangerous pollution. (Fig. 48.) Moreover, the influence of pumping or other sudden withdrawal of water from the well is even more important, since it extends a distance from 15 to 150 times the temporary depression of the water-level, and impurities may thus be drawn into the well which ordinarily would tend to flow away from it. (Fig. 49.)

Excepting the bacteria, which pass freely through almost all soils when resistance to the water-current is markedly diminished, only such portions of the pollution as can be dissolved may reach the water in the well; and

it is a fact that many waters thus polluted are sparkling and clear, with a pleasant taste and no bad odor, so that any suspicion as to their real character may be wanting. Moreover, even though specific disease germs be absent, there is always danger that the contamination may become so concentrated as to produce serious results, and this may occur in various ways: (*a*) the well may be so deep or the character of the soil such that in ordinary weather the liquid passing through the soil is so purified that it imparts no harmful properties to the water; but if the soil is being continually infiltrated with dangerous

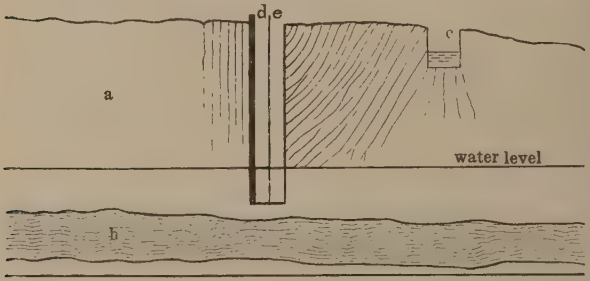


FIG. 48.—Representing the difference of percolation about cased (*d*) and uncased (*e*) wells: *a*, soil and gravel; *b*, clay or rock; *c*, cesspool.

impurities and if, at length, heavy rains or continued wet weather supervene, there may be more and more of these impurities dissolved and carried into the well until the proportion of harmful matter in the water passes the safety-line, and as a result there is marked illness or increased predisposition to disease among those using the water; or (*b*) in continued dry weather the ground-water may be lessened to such an extent that the impurities that were formerly well diluted become sufficiently concentrated to cause sickness, even though there be no unusual pollution of the soil about the well; or (*c*) the water-level

in the well being suddenly or persistently lowered, a greater area is drained and additional collections of sewage may flow into the well. (Fig. 49.)

Deep Waters.—Deep wells are those which pass through an impermeable stratum, and so do not get their supply from the subsoil-water. The relative depth of two wells is no exact criterion as to their classification, as the shallower one may really be a "deep" one and the deeper a "shallow" one, according to the presence or absence of the *impermeable* stratum. Artesian wells are very deep wells, piercing one or more impermeable strata.

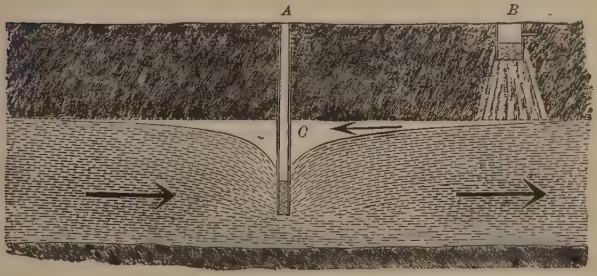


FIG. 49.—Showing depression of water in shallow well caused by pumping: *A*, well; *B*, cesspool; *C*, underground water-curve. (After Field and Peggs.)

Sometimes the water rises and flows out of the mouth of a deep well, in which case the supply is drawn from a water-bearing stratum between two impermeable ones, and which has its only outcroppings higher than the top of the well. (Fig. 50.) The water accumulates in this natural reservoir above the level of the well-mouth, and is forced out when an opening is made through the uppermost impermeable stratum. Deep well-water is apt to be of much better quality than that from shallow wells, since it usually represents the total percolation from a very large extent of ground surface, within the limits of which the

combined areas and amount of pollution are insignificant in comparison, any possible impurities in the water being consequently reduced by dilution to much below the danger-point. It is for the same reason that there is such a difference in the quality of spring-water and of that from most shallow wells. Though the two waters seem to have a common source, one is the composite water of a large district, in which the average impurity or contamination per unit of surface may be infinitesimal; the other is mainly the special percolate from a limited area, which is, for the reasons given, particularly liable to be highly and dangerously polluted.[1]

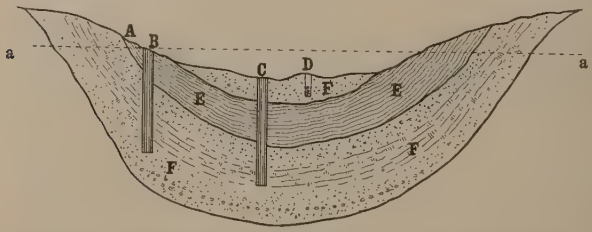


FIG. 50.—Representing the spontaneous flow of deep or artesian wells, *B* and *C*. *a*, *a*, water-level in deep pervious strata, *F*, *F*; *A*, intermittent spring at out-cropping of *F*, *F* above impermeable stratum, *E*, *E*. *D*, shallow well in upper pervious strata. (Wilson.)

It is also to be remembered that in many of the strata or beds supplying deep or artesian wells the water has been collecting for a very long time, possibly even for centuries, and it is incredible that organic pollution should persist with power for harm through periods of such duration.

Artesian or deep well-water will also likely be very free from organic matters, but possibly heavily charged with mineral salts. Should these latter not be present, the water will probably be of excellent quality; though if the

[1] Of course, the water in shallow wells, as in others, is being continually changed by the onward movement of the underground current; but where this is slow in comparison with the percolation from the surface, the impurities of the latter will be in excess in the well-water.

well be very deep, it may be too warm for immediate use as a potable water.

Frequently well-water, and that most often from shallow wells, is the only kind available, especially in country districts. In such cases care must be taken that impurities are kept out of the well by all possible means. If this be done, water may often be had of excellent quality. The area about all wells should be kept clean, and the well should be as distant as possible from any source of contamination, especially if the latter be a constant one. Wells should be walled or cased, shallow wells to below the water-level and deep wells to the first impermeable stratum, if possible, in order to cause the water to percolate

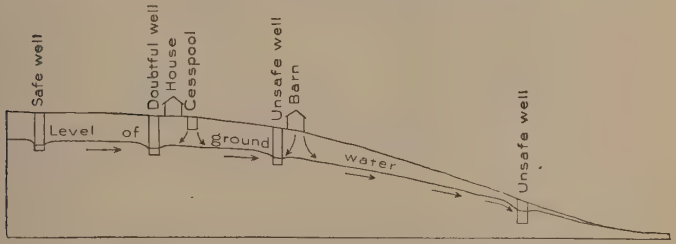


FIG. 51.—Diagram showing ordinary location of farm well. (U. S. Geological Survey, Water-supply Paper 255.)

through as much soil as possible before entering the well, in this way checking the rapidity of its descent and prolonging the biological action of the top-soil.[1] Wells should also have a properly constructed covering and curb,

[1] As the saprophytic and nitrifying bacteria are only found normally in the first few feet of top-soil, where the conditions are favorable to their existence and growth, we cannot expect to have any further action by them after the water reaches its underground level and begins to move toward its outlets. Nor will there be any filtration in this onward progress, for that has been accomplished in the upper layers. It is for this reason that the filtrate from cesspools and similar pits is not organically purified, but is especially obnoxious and dangerous as it traverses the soil, for the bottoms of such pits are usually below the biological level, and there is also in them a lack of the oxygen necessary to maintain the action of the nitrifying bacteria.

to keep out splashings and drippings of muddy or dirty water. (Fig. 52.)

In this connection Sedgwick says: "Excepting those cases in which cracks or fissures in the earth allow direct communication between polluting sources and wells of drinking-water, the author is strongly of the opinion that in most cases in which infection exists in wells, the polluting material has found its way in from the top." "When one reflects on the carelessness with which wells used as sources of drinking-water are exposed to the access of filth from the top, such wells often being only loosely covered by planks, it is easy to see that from the boots of work-

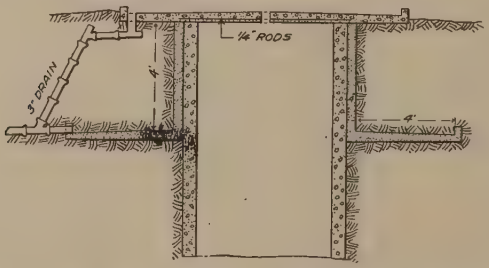


FIG. 52.—Well protection. (Bulletin 57 of the U. S. Dept. of Agriculture.)

men, or from children playing on the planks, or from poultry walking about and carrying infection on their feet, pollution may take place."[1]

We must not forget that wells drain a large area. As the ground-water has a constant movement in the direction of natural outlets, the well should be so located that the current flows *from* it toward any near-by cesspool or other source of pollution. (Fig. 51.) The direction of the underground current can generally be determined by noting the location of the nearest spring or water-course, by observing the dip of the underlying strata, or by digging

[1] Principles of Sanitary Science and the Public Health, 1902, p. 351.

holes at equal distances about the well and dissolving salt or an aniline dye in them in turn, and testing the water from the well after a time for the salt or color. If a well be much deeper than a neighboring cesspool, it may drain from the latter, even in opposition to the ground-water current, especially if the water in the well be suddenly lowered. Again, dangerous impurities have been carried into wells from long distances through fissures or crevices in rock. Harrington cites the case of a well which,

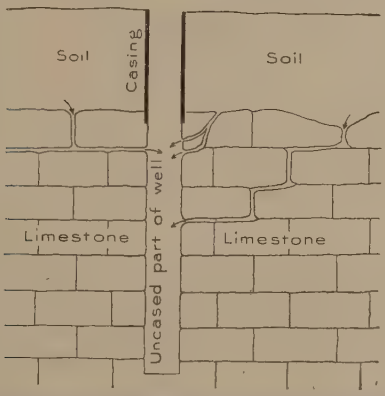


FIG. 53.—Diagram showing danger of pollution where casing is carried only to rock. (U. S. Geological Survey, Water-supply Paper 255.)

"bored 500 feet into red sandstone, drained, through fissures, all the shallow wells in the vicinity. These being of no use as wells, were then utilized as cesspools, and draining again through the fissures, caused the well to become so foul that it had to be abandoned." (Figs. 53 and 54.)

The water from the well should be frequently tested for chlorides and nitrates, these usually indicating sewage contamination, and this should be done especially after heavy rains and also when the water in the well becomes low. The

taste and odor of the water should also be noted after standing for a time or on being heated. Some other sources should be sought whenever such tests show contamination or when there are cases of infectious disease near at hand. Boiling the water and filtration are always to be recommended whenever there is the least suspicion as to impurity or infection.

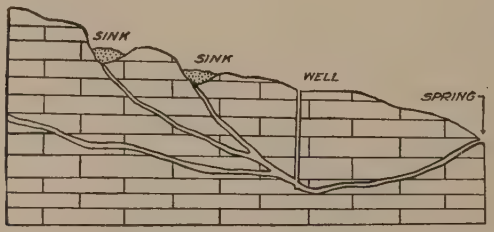


FIG. 54.—Pollution of subsurface-water in limestone. (Bulletin 57 of the U. S. Dept. of Agriculture.)

Shallow or subsoil wells in thickly settled towns should not be used to supply drinking-water or cooking-water, as the soil is always more or less saturated with filth and sewage, and it is practically impossible in such places to locate a well which will not be in constant danger of receiving harmful impurities from some source or another.

In an investigation[1] made by the author in 1904 he discovered that the incidence of typhoid fever is greater in districts essentially rural, and not in those which include the great cities, many of which latter are known to have had high death-rates from this disease, and all of which have water-supplies which may, if not properly cared for, serve as common carriers of infection to their enormous populations. As the data from which this study was made were taken from the Report on Vital Statistics of the U. S. Census of 1900, it must be remem-

[1] Typhoid Fever in Relation to the Urban and Rural Population of the United States, American Medicine, April 22, 1905, pp. 649–652.

bered that all cities and towns of less than 8000 population were at that time classified with, and that they collectively made up a large, if not the greater part of the so-called rural population. Now, in the smaller towns and villages it is more than probable that the inhabitants are supplied from private and shallow wells and cisterns, rather than from common sources, such as reservoirs, springs, artesian wells or modern filter plants, and, consequently, there is continual danger in such communities of the water being contaminated by neighboring cesspools and other sources of pollution, this danger rapidly increasing as the villages grow in size, since the entire body of ground-water supplying the wells is correspondingly more liable to be polluted beyond the limit of safety or to become at any time the common carrier of infection. Hence it is easy to understand how the so-called rural populations actually have, as a rule, a relatively higher sick- and death-rate from typhoid fever than do the dwellers in large cities; and it should be equally evident that it will be the part of wisdom for small communities that have not already done so to employ every possible means to secure improved and non-polluted water-supplies for the common use of their respective populations.

The decision as to the quality of any water must in each case be determined by all the circumstances available which relate to it, and these should all be thoroughly investigated before rendering an opinion, as some of them may counteract the others. However, other things being equal, the value of a water will probably be in accord with the following table:

Wholesome	1. Spring-water,	Very palatable.
	2. Deep well-water,	
	3. Water from unpolluted streams,	Moderately palatable.
Suspicious	4. Stored rain-water,	
	5. Surface-water from cultivated land,	
Dangerous	6. Sewage-polluted river-water,	Palatable.
	7. Shallow well-water,	

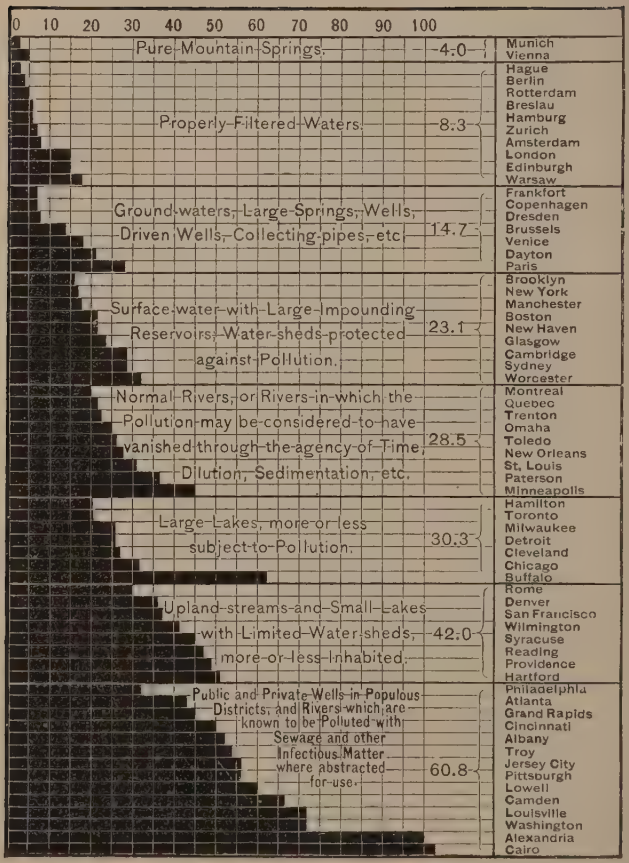


FIG. 55.—Showing death-rates from typhoid fever in 1894 in sixty-six cities, grouped according to the quality of their drinking-water. (Reproduced with the permission of the author, Mr. James H. Fuertes, and of the Association of Civil Engineers of Cornell University.)

We may also classify waters as follows: (1) Pure and wholesome water; (2) usable water; (3) suspicious water; (4) dangerous water. (See chart on page 210 and table on page 268.) Pure waters and usable waters may be used without filtration; those of the third class should be filtered before distribution, and also at the house before use, if possible, and a purer source sought or all sewage-pollution prevented. Those of the fourth class should not be used at all except when absolutely unavoidable, and then only after purification by all the means at command.

Inasmuch as most large cities must from necessity furnish a water of the second or third, and occasionally even of the fourth class, such water should be purified as much as possible before distribution by storage for a time in settling reservoirs and by some effective system of filtration, combining these with chemical treatment if necessary. As much of the organic matter is oxidized, and many of the pathogenic bacteria are destroyed by saprophytes and other causes while the water is standing in the settling reservoirs, and as properly constructed and well-managed filters are even more efficacious to this end, a water originally suspicious or worse may often be made usable by the above means properly employed. Not only must the storage reservoirs and filtering apparatus be kept clean and in good working order, but care must also be had that the distributing apparatus does not permit polluted ground-water or sewage to be drawn in through leaks in the mains at times when the flow is intermittent, and that lead pipes are not used for conveying drinking-water if the character of the water is such that it acts on that metal.

A good potable water should be perfectly clear, free from odor or taste, cool, well aërated and, if possible, soft or with only a mild degree of hardness. Circumstances must determine the amount of dissolved matters permissible; what is an excess in one case might not be so in another.

DISEASES CAUSED BY IMPURE DRINKING-WATER.

A polluted water may carry the organisms of infectious diseases, or it may cause or favor the development of diseases which are not due to specific germs. In addition to these, and of at least equal importance from a sanitary point of view, is the depressed state of the system that the habitual use of impure drinking-water causes, and the predisposition to disease that ensues. By the faculty of accommodation and through long habit a community may become so protected against an impure water as to manifest no striking symptoms, while strangers may be seriously affected by it; but even in such a case the condition of those habitually using the water will probably be more or less depressed and not that of perfect health.

The non-infectious diseases likely to be caused by impurities in the drinking-water are primarily those affecting the alimentary tract, as dyspepsias, diarrheas, and other disturbances having their origin in severe or chronic gastric or intestinal irritation. So, also, impure water, even though it does not contain the actual germs, may have much to do in bringing on an attack of typhoid fever, specific dysentery or other infectious disease by so lowering the resistance of the body as to make it especially receptive to the cause of the malady when introduced from another source.

Large quantities of the sulphates of calcium and magnesium are thought to have special influence in causing dyspepsias, with loss of appetite, pain at the epigastrium, etc. An excess of iron in water is also prone to produce constipation, headache, loss of appetite and malaise. The formation of vesical calculi is supposed to be due to mineral or inorganic impurities, although the true relation of impure drinking-water to this trouble is still unsettled. "It has long been a popular opinion that drinking limewaters gives rise to calculi of the oxalate and phosphate of calcium." The "opinion that impure water is the cause of goitre is as old as Hippocrates and Aristotle," but the

present belief is that it is due to a lack of sufficient iodine in the potable waters of the locality or district in which the patient resides. There are certain areas of this country in which goitre is quite common, manifesting itself in fairly large percentages of adolescent boys and especially girls, and in some of these areas remarkable results in preventing as well as curing it have been achieved by the periodic administration of small quantities of iodine or its salts to the pupils in the public schools.

Diarrhea may be caused by any of the following impurities in water: suspended substances of any kind, but especially those of fecal origin; dissolved animal, vegetable, or mineral matters, and fetid gases. The diarrhea produced by any of these contaminants may be so severe as to simulate true dysentery and cause doubt as to the diagnosis.

Certain metals may be taken up from the earth's strata, or from the lining of cisterns, pipes, etc., and may produce their characteristic toxic symptoms in the system. Lead is one of these metals, and it will be well to note here the waters that are especially apt to take up this metal. Pure waters and those containing much oxygen act powerfully on lead, as do those containing organic nitrates and nitrites, especially ammonium nitrate. Waters containing carbon dioxide and the salts of calcium and magnesium and those free from absorbed gases act least on lead, and carbon dioxide seems even to protect lead by forming an insoluble carbonate on leaden surfaces, but water containing carbon dioxide may take up lead for a time from new pipes until the insoluble carbonate is deposited within them. It has also been shown that in some cases wherein cold water does not act upon the metal, hot water will dissolve a small but appreciable quantity of it. Copper, zinc, and arsenic are also metals that may be taken up by certain waters, and that may cause serious results from the use of the latter. Lead is more easily dissolved if other metals are in contact with it, probably owing to electrolytic action. Lead should not be used for pipes nor to line cisterns

unless suitable tests show that the water does not affect it, nor should any water be used in which the tests show more than one-thirtieth of a grain of lead per gallon.

Of the infectious diseases, germs of typhoid fever, cholera, and dysentery are usually carried into the system by the drinking-water, while scarlet fever, diphtheria, and kindred diseases may possibly be transmitted occasionally by the same means.

For a long time the belief that malaria was very frequently, if not most often, transmitted by the drinking-water, was held by many sanitarians, and there seemed to be much circumstantial evidence to substantiate this opinion. However, careful scientific investigation has proved that this disease can be and is due to direct inoculation by at least one species of mosquito, which acts as an intermediary host in the life-cycle or development of the malarial organism (Plasmodium malariæ), and all authorities now believe that the disease is transmitted only in this way.

But, as with the impurities causing non-infectious disturbances, water containing disease germs may sometimes be used for a long time by those accustomed to it without the development of the specific malady, and it may only be after the system is weakened by excesses or other predisposing conditions that the disease manifests itself; or it may happen that only strangers and non-immunized inhabitants incur the disease. It has been suggested that this immunity is probably brought about by the very gradual introduction into the body of the disease germs and their poisons, so that residents of the locality are not susceptible to the small numbers or quantities of these which are sufficient to give rise to the symptoms of the particular diseases in newcomers.

It is sometimes difficult to determine just when or how a water-supply has been infected with pathogenic organisms, but it is now well known that a person who has recovered from a transmissible malady may continue to carry about in his body and to excrete the disease germs for a long time. Thus the bacteria of typhoid fever

may be found for months in the urinary or fecal excretions of a considerable proportion of those who have had that disease and, in some, for even years thereafter; many such cases having been reported by numerous investigators. It is therefore easy to comprehend how such a person, going from place to place, might infect not one, but many sources of water-supply.

The following table gives data relating to some notable epidemics of typhoid fever:

Location.	Date.	Population.	Cases.	Deaths.
Lausen, Switzerland .	1872	780	144	...
Caterham, England .	1879	5,800	352	21
Plymouth, Pa. . .	1885	8,000	1,104	114
Ithaca, N. Y. . .	1903	13,000	1,300	78
Butler, Pa. . . .	1903–04	18,000	1,348	111

Many instances have been recorded which practically prove the transmissibility of infectious diseases by means of drinking-water, and of these, reference may be made to the epidemics of typhoid fever at Lausen[1] in Switzerland, at Plymouth, Pa.,[2] Butler, Pa., and Ithaca, N. Y.; and of cholera in London.[3] The writer himself had an opportunity of investigating an epidemic of typhoid fever in a small village in North Carolina.[4] In this there were only four or five in about sixty cases which were not undoubtedly due to contamination of the subsoil-water by the infected excreta from the first case; and of four of the exceptions (which were in one family), the first was in all probability infected by using the water while in attendance upon sick neighbors, and the others by direct contagion from the first. It was also shown that, with the exception of these four, the cases all developed

[1] Pepper's System of Medicine, vol. i, p. 250.
[2] Rohé's Text-book of Hygiene, 2d edition, p. 63.
[3] Ibid., p. 64.
[4] University Medical Magazine, May, 1892.

directly along the lines of natural drainage leading from the residence of the original case—a boy who came to the village sick with the disease—and that the latest cases to develop were those most remote from the starting-point of the infection.

Moreover, in most large cities of this and other countries the typhoid fever death-rate is accepted as the direct index of the character of the water-supply, and it seems to be a

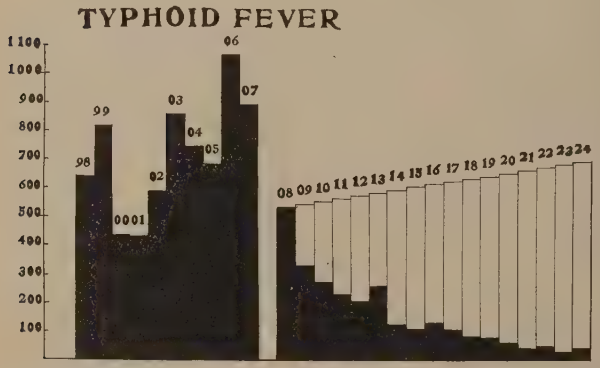


FIG. 56.—Chart showing the number of deaths and reduction in the death-rate from typhoid fever in Philadelphia following the introduction of filtered water and the pasteurization of milk (1913). This represents a total saving of over 8000 lives.

fact almost without exception that any marked improvement in the latter will be followed by an immediate and positive reduction in the former. (See chart on page 223.) The same may also be said to hold good in regard to diarrheal diseases; while in eastern North Carolina there has been a marked reduction in the prevalence of so-called malarial fevers—which are probably typhoid or paratyphoid in reality—as a result of the efforts of the State Board of Health, to persuade the people to substitute rain-water

or deep well-water for the subsoil-water which was almost universally used a few years ago.[1]

The ova of certain parasites, such as tape-worms or round-worms, may often be taken into the system with the drinking-water, and these upon developing may cause disturbances that may require more than the slight attention usually given to them. Any attack of convulsions in a child or other severe manifestation of reflex action should lead to the inquiry as to whether these parasites may not be present, and whether the water-supply has not been the source of invasion. It is now known that the parasite of ankylostomiasis or hook-worm disease may also be carried by and introduced into the human body by the drinking-water.

Regarding the foregoing remarks, Parkes makes the following statements: "(1) An epidemic of diarrhea in a community is almost always owing to either impure air, impure water, or bad food. If it affects a number of persons suddenly, it is probably owing to one of the last two causes, and if it extends over many families, almost certainly to water. But as the cause of the impurity may be transient, it is not easy to find experimental proof. (2) Diarrhea or dysentery constantly affecting a community, or returning periodically at certain times of the year, is far more likely to be produced by bad water than by any other cause. (3) A very sudden and localized outbreak of typhoid fever or cholera is almost certainly owing to the introduction of the poison by water. (4) The introduction of the ova of certain entozoa by means of water is proved in some places, probable in others. (5) Although it is not at present possible to assign to every impurity in water its exact share in the production of disease, or to prove the precise influence on public health of water which is not extremely impure, it

[1] According to Hazen, for every death from typhoid fever prevented by the purification of a polluted water-supply, two or three deaths are prevented from other causes. This statement, Sedgwick says, he has been able to confirm and to establish as conservative.

appears certain that the health of a community always improves when an abundant and pure water-supply is given; and, apart from this actual evidence, we are entitled to conclude from other considerations that abundant and good water is a prime sanitary necessity." The statistics already given and those to come in later pages are confirmatory of the correctness of this last assertion, and sanitary authorities now realize that, in addition to the mortality from typhoid fever, the main cause of an increase in the death-rate from diarrheal diseases is more often to be fairly attributed to a contaminated water-supply than to improper food or untoward temperatures. Even with respect to cholera infantum (which is generally supposed to be principally due to the influence of excessive heat upon the infant and its food) a number of epidemics show a closer relation to impure water-supply than to temperature-changes.

THE PURIFICATION OF WATER.

Impurities in water may be either solid matters in suspension or dissolved substances, and may be organic or inorganic. Any turbidity is due to solid particles, and water free from these is clear, though it may be colored more or less deeply by dissolved matters. But a clear water may contain such solid bodies as bacteria, animalculæ, ova of parasites, etc., which are too minute to be seen with the naked eye. Whether harmful or not, all impurities should be removed in so far as it is possible from all supplies of drinking-water. This may be done to a considerable extent with large volumes of water before distribution to consumers, and should always be attended to by the latter if the water is not already clean and within the limits of safety when they receive it. In fact, a large city at the present time can scarcely have a more important subject for consideration than that of obtaining and supplying the purest possible water-supply to its people. There will always be a tendency among many to allow

matters to continue as they are or as they have been in the past, and a decided objection by others to incurring additional expense for what may seem to them only esthetic reasons; but no matter what may be the cost of providing a reasonable supply of pure water for any city's personal and domestic uses, a very little consideration will show that such expenditure is true economy from solely a financial point of view, even though we ignore the misery and sorrow of the sickness and deaths that are due to the use of a polluted water.

As has been stated by the excellent authority quoted above, "the health of a community always improves when an abundant and pure water-supply is given. The death of 3400 persons from cholera followed the temporary supply of unfiltered water by the East London Water Company in 1866, while the rest of London remained nearly free from the disease;" and in 1892 "Hamburg lost 8605 citizens from the same disease alone," regarding which "the health authorities found that the principal cause of this epidemic was the polluted water-supply,"[1] while the neighboring city of Altona, which used filtered water, was comparatively free from the disease.

Again, after the scourge of typhoid fever in Plymouth, Pa., in 1885, when there were, within a few weeks, 1104 cases and 114 deaths in a population of less than 8000 as a result of pollution of the water-supply by a single person, great care was taken to determine the exact cost of the "visitation," as some would term it. It was found that the actual expenditure for the care of the sick was $67,100.17; loss of wages by those recovering, $30,020.08; a total of $97,120.25, to which should be added a number of times the $18,419.52 that those who died were earning per annum when taken sick. How much cheaper in comparison would a protecting filter-plant have been! Overlooking special epidemics, and considering the *average* annual typhoid death-rates of our cities, we find that

[1] Hazen, Filtration of Public Water-supplies, 1895.

experience, both here and abroad, shows that with a pure water-supply a maximum death-rate from this disease is 25 per 100,000, and that any city may reasonably expect to secure even a lower rate by observing proper precautions. A notable betterment in this respect in recent years is shown by the records of the larger cities of the country. Only five cities in the registration area of over 25,000 population (and none of over 50,000) had a typhoid mortality-rate in 1922 higher than that stated above, this

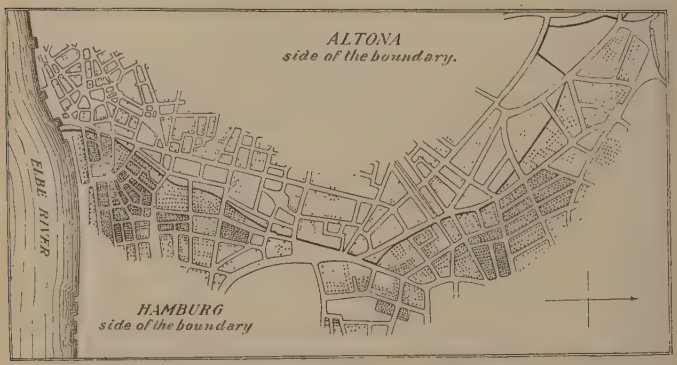


FIG. 57.—Portion of the boundary line between Hamburg and Altona. The dots indicate cases of cholera. (Harrington.)

as against thirty-one cities of this size in 1916, while the sixty-seven larger cities of over 100,000 population, totaling over 28,000,000 individuals had the remarkably low average of 3.23 deaths per 100,000, three of these cities going through the year without a single recorded death from typhoid fever.

Lawrence, Mass., with a population of 44,654 in 1890, built a filter at a cost of $67,000, saved enough lives, at $5000 per head, to pay for it within the first four months that it was in use, and had a reduction of almost

60 per cent. in the typhoid death-rate within a year. In Chicago, when the similarly estimated loss from typhoid deaths in the city and suburbs amounted to over $10,000,000 in 1891, the abandoning of a shore inlet near the mouth of the sewage-polluted Chicago River in 1892 resulted in a reduction of 60 per cent. in the typhoid mortality during the following year.

But it is only when one realizes that an increase in the mortality from any cause of only 1 in 1000 of population means 1000 additional deaths per annum in a city of 1,000,000, that he can appreciate the meaning and the loss in capitalization to the municipality of the exceedingly high typhoid mortality that obtained in some of our cities. Philadelphia's death-rate from this disease has dropped from an average of 61.3 per 100,000 of population for each of the five years, 1903–1907 inclusive, to 2.8 for 1922, the installation of filter-plants for the entire water supply of the city having been begun in 1902 and completed in 1911. This represents a saving of over 1100 typhoid deaths per annum based on the population of the city in 1922, and probably as many more from other diseases due to impure water. At the valuation of $5000 per capita—not an excessive estimate according to the finding of courts in cases of death by accident, and, inasmuch as most typhoid cases occur during the working age of from fifteen to fifty years—in one municipality, with an average population of about one-third of a million, the excessive typhoid deaths *above* a 25-per-100,000 rate amounted in five years (1900–1904) to the astounding total of 1888, representing in capitalization at the above life valuation the sum of $9,440,000. Nor must it be forgotten that these figures do not include the cost of medical attention and nursing for the thousands who were sick, nor the loss of time and employment by those who recovered, nor do they consider the financial loss due to sickness and deaths from diseases other than typhoid fever that may be fairly attributed to polluted water-supplies. Can anyone doubt where true municipal economy lies, and is there not

abundant opportunity for sanitary education and work in this direction alone for many years to come?[1]

Purification before distribution may be by either or all of three methods: subsidence, chemical treatment, and filtration.

Subsidence.—This method consists in allowing the water to stand in large reservoirs until the greater part of the suspended matters have fallen to the bottom. If sufficient time be given, much of the organic matter, whether solid or dissolved, will be decomposed or reduced to simpler compounds by the action of the sunlight, oxygen, animalculæ, saprophytes, etc. Most of the bacteria also, especially the pathogenic species, will disappear either by sedimentation, by death from lack of favorable conditions, or on account of the germicidal effect of the sunlight. "The great source of ultra-violet radiations and 'the cheapest disinfectant known,' as Duclaux puts it, is the *sun*. Rivers and lakes are freed from a great part of their bacterial contents by the bactericidal powers contained in the sun's rays."[2] Consequently, a water originally quite impure may be much improved by this method alone, while if it is used in conjunction with and preliminary to filtration it will be additionally advantageous in that it reduces the cost of the latter by lessening the frequency and expense of cleaning the filters.

What the capacity of the reservoirs and the time of storage should be, depend on circumstances. If it is the only method of purification employed, and especially if the water is very foul, the longer the time of storage the better. Again, if the source of supply is variable in output or if it is liable to excessive pollution for limited periods, the capacity should be such, if possible, that

[1] According to the Report on Mortality Statistics of the U. S. Census Office for 1922, the deaths from typhoid fever in the "registration-area" in that year number 6981. The typhoid death-rate for the entire "registration-area" dropped from 35.9 per 100,000 in 1900 to 7.5 in 1922, and the average for the last five years (1918–1922) was 9.22.

[2] Von Recklinghausen, Journal of the Franklin Institute, December, 1914, p. 683.

water need not be collected during the emergency. On the other hand, if the water is to be subsequently filtered, the capacity of the reservoirs and time of storage need not be so great. Most German authorities on filtration hold that preliminary sedimentation for twenty-four hours or even less is sufficient, most of the solid matters being precipitated within that time, if at all, and the filters being relied upon to remove the remainder, especially the finer

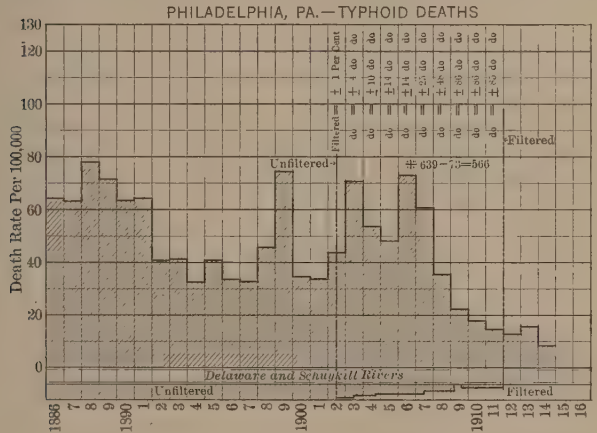


FIG. 58.—Chart showing the influence of filtered water upon the typhoid death-rate in Philadelphia.[1]

particles and the bacteria. The English practice is to store the water for a longer time, though local causes related to the source of supply are the reason for this. Thus the Lea and Thames, from which the London companies take much of their water, are subject to extra pollution in times of flood, which are usually of short duration, and a sufficient reserve for such periods is of obvious value.

[1] FIGS. 58, 59, 60 and 67 are available through the courtesy of the Bureau of Water of the City of Philadelphia.

All storage reservoirs should, of course, be kept free from extraneous contamination, and should be cleaned from time to time. This necessitates an arrangement in pairs or groups, or a partitioning of large reservoirs, so that one part may be cleansed without putting the rest out of service. Weeds should be destroyed, as they sometimes give an unpleasant taste to the water. The water may also have a bad taste or odor from algæ and other species of

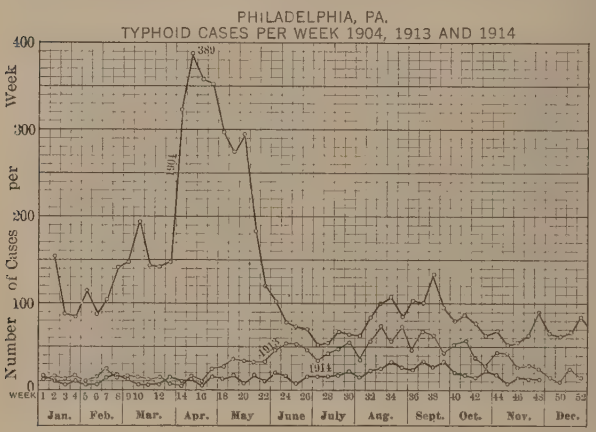


FIG. 59.—Chart showing the reduction in rate and change of seasonal incidence of typhoid fever in Philadelphia following the general supply of filtered water to the entire city.

minute plants which especially favor a pure water exposed to sunshine. They are not known to be harmful, but it may be necessary to cover the reservoirs to get rid of them and their unpleasant properties. On the other hand, it may be necessary to aërate the water as it enters the reservoir, either through fountains or over rock-work, to get rid of the disagreeable odors or tastes due to the algæ or to industrial wastes, especially in the winter when

the source from which the water is taken is frozen over, the ice preventing the escape of the gases causing the offensiveness.

By the creation of great impounding reservoirs in the Catskills, New York City is providing a supply which, taken with that from the Croton water-shed, its previous source of supply, gives a total of eight hundred million gallons daily. From these reservoirs the water is conveyed for 119 miles to the terminal reservoir on Staten Island through the greatest aqueduct ever constructed, passing under the Hudson at a depth of almost 1400 feet below the river level and 35 miles of it being through solid rock far below the surface.

Chemical Treatment.—Where a water is very hard or contains an excess of mineral matter it is frequently of advantage to treat it chemically. If the hardness is due to calcium bicarbonate in excess, it may be removed by the addition of a solution of calcium hydroxide to the water, *insoluble* calcium carbonate being formed and precipitated. The change is represented by the equation:

$$CaH_2(CO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O.$$

Clark's process, based on this reaction, is as follows: About fourteen or fifteen hundred-weight of lime is allowed to each million gallons of water, the actual quantity of lime depending on the amount of bicarbonate in the water. The lime is slaked in a tank into which the water to be treated flows; the mixture is well stirred and then allowed to stand for from three to twelve hours, when the supernatant water is drawn off, the tank cleaned, and the process repeated. "The stirring motion not only accelerates and completes the chemical action, but has a tendency to gather together the fine particles of carbonate of lime formed by the softening chemicals into comparatively large masses which settle with great rapidity as soon as the water flows into the settling tank." The water is not only softened in this way, but the precipitate also usually carries down with it

FIG. 60.—Purification of water by the Clark process.

much of the solid impurities and organic matter in the water. This process is extensively used in England, where much of the available water is derived from the underlying chalk-beds, and thus has a superabundance of the bicarbonate; but the writer is unaware that it finds any general application in this country, though it might be an advisable method of treatment in certain of our limestone districts.

If alum (aluminum sulphate) be added to an impure water, a decomposition of the salt occurs, the acid portion combining with the bases in the water and forming a flocculent precipitate of insoluble basic sulphates and aluminum hydroxide, which entangles in it and carries down the suspended impurities in the water, beside removing much of the dissolved organic and coloring matters. Moreover, careful experiments have shown that the addition of only about one grain of alum per gallon, followed by thorough agitation and subsequent settling for twenty-four hours, will almost invariably give a water free from germs and one that will tend to remain sterile for a considerable time; this possibly being due to removal of the food-supply of the bacteria.[1]

The use of alum is especially advantageous when a water contains a very fine silt or the like in suspension, and which is not removed by subsidence even after a considerable time. It is also to be used in conjunction with or preliminary to mechanical filtration, which latter, at the usual rate of operation, is oftentimes practically dependent upon alum for the furnishing of a clear, safe water. Comparatively little alum is needed, even with a very dirty water—usually not more than one or two grains per gallon, and if the supply is practically adjusted to the condition of the water, as it should be, the extremely minute quantity of free alum that may sometimes pass through the filters is harmless and unimportant.

Should the water be lacking in sufficient bases, which,

[1] V. and A. Babes, Centralblatt für Bakteriologie und Parasitenkunde, 1892, vol. ii, No. 45.

however, is extremely improbable, it might contain when filtered a very little free acid, which can be readily neutralized by the addition of a correspondingly small quantity of sodium hydroxide or carbonate, the resulting salt affecting neither the healthfulness nor the palatability of the water. It has been suggested that the alum be first decomposed by the addition of sodium hydroxide, then washed free from the resulting sodium sulphate and the flocculent aluminum hydroxide added to the water, thus avoiding the chance of there being either free alum or acid in the cleared water; but experiments show that the results are not so good as when alum alone is used.

Regarding the danger from the use of water purified by the addition of alum, Hazen says: "Although alum in large quantities is undoubtedly injurious to health, it is neither a violent nor a cumulative poison; and the proposition that one part of alumina in a million parts of water is injurious to health must be regarded as conjecture rather than as a matter of proof or even of probability."

The Anderson process, which consists in agitation of the water with metallic iron before filtration, has been employed at Antwerp and elsewhere; but it is not clear that with large quantities of water better results are obtained than by simple filtration. The idea is that some of the iron is converted into soluble ferrous carbonate, which then oxidizes to insoluble ferric hydroxide and carries down with it the suspended and many dissolved impurities, and thus facilitates their removal by sedimentation and filtration. The difficulty in using this process on a large scale seems to be that the carbonate is not formed quickly enough, and also that too much of the iron may remain in solution even after filtration.

A chemical method that has come into vogue comparatively recently involves the addition to a polluted water of small quantities of the hypochlorites, especially that of calcium, and still later of chlorin alone. To quote from an experimental study of the process by E. J. Tully, of the University of Wisconsin, "the process is essentially

one of oxidation," many bacteria and much organic matter being destroyed by the nascent oxygen liberated in the reactions occurring when the hypochlorites are

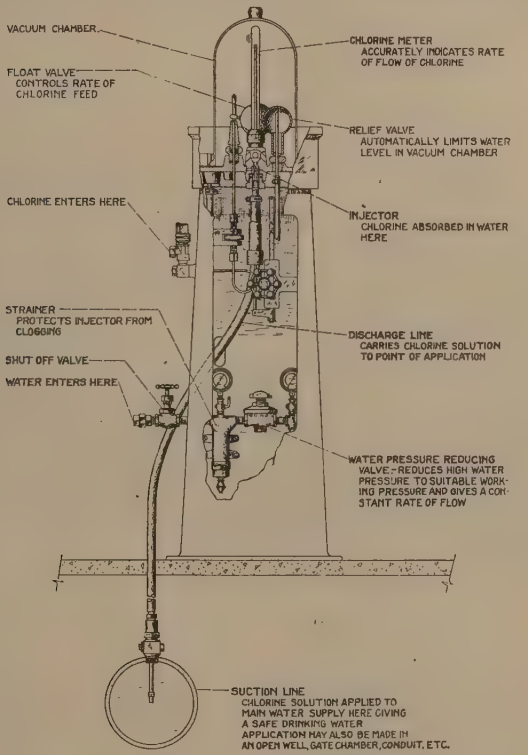

VACUUM CHAMBER
FLOAT VALVE CONTROLS RATE OF CHLORINE FEED
CHLORINE METER ACCURATELY INDICATES RATE OF FLOW OF CHLORINE
RELIEF VALVE AUTOMATICALLY LIMITS WATER LEVEL IN VACUUM CHAMBER
CHLORINE ENTERS HERE
INJECTOR CHLORINE ABSORBED IN WATER HERE
STRAINER PROTECTS INJECTOR FROM CLOGGING
DISCHARGE LINE CARRIES CHLORINE SOLUTION TO POINT OF APPLICATION
SHUT OFF VALVE
WATER ENTERS HERE
WATER PRESSURE REDUCING VALVE:-REDUCES HIGH WATER PRESSURE TO SUITABLE WORKING PRESSURE AND GIVES A CONSTANT RATE OF FLOW
SUCTION LINE CHLORINE SOLUTION APPLIED TO MAIN WATER SUPPLY HERE GIVING A SAFE DRINKING WATER APPLICATION MAY ALSO BE MADE IN AN OPEN WELL, GATE CHAMBER, CONDUIT, ETC.

FIG. 61.—Manual control chlorinator solution feed.
(Courtesy of Wallace & Tiernan.)

added to water containing them. His conclusions are as follows:[1]

[1] American Journal of Public Health, May, 1914, p. 435.

"Chemical disinfection offers a means whereby a very satisfactory purification of water may be accomplished. Comparisons on a cost basis of the methods of chemical disinfection make it apparent that calcium hypochlorite is the most satisfactory and efficient agent at the present time for water disinfection.

"The amount of organic matter in the water practically determines the quantity of calcium hypochlorite that it is necessary to use. As a general rule, practical sterilization

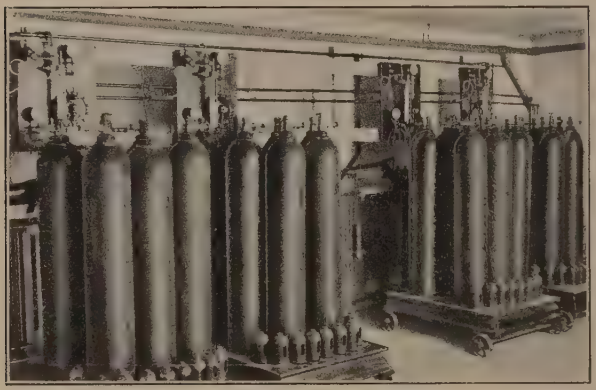


FIG. 62.—Chlorinator installation, Esopus Creek, New York water supply. This chlorinates one of the streams entering the Ashokan storage reservoir. (Courtesy of Wallace & Tiernan.)

may be accomplished by the application of from 0.1 to 1 part per million of available chlorine, but occasionally concentrations of 2 and 3 parts per million of available chlorin are necessary to effect desirable results with rather highly colored and turbid waters.

"The removal of B. coli and intestinal organisms is usually more complete than that of the total organisms. Under the conditions of the laboratory experiments, the results of the hypochlorite disinfection on typhoid organ-

isms and intestinal bacteria in the various waters were practically identical. It is therefore safe to assume that the viability of pathogenic bacteria under working conditions in practical water disinfection is no greater than that of the typhoid organism, or intestinal bacteria as a whole. Consequently, the disinfection effected by calcium hypochlorite relative to the total bacterial removal may be referred directly to pathogenic bacteria with assurance of reasonable accuracy.

"The slight odor and taste of chlorine imparted when somewhat more than 0.5 part per million is applied disappears in a short time, leaving the water entirely acceptable from a sanitary stand-point; and as the hardness is not materially increased by the application of the usual small quantities employed, the treated water is not rendered unsuitable for industrial purposes.

"There is no apparent reason for believing that the results are not of general applicability. The reactions involved are particularly free from interference on the part of the mineral constituents of normal waters; and normal variations of temperature have no effect on the final results. The efficiency of the process is also entirely independent of the secondary or after-growth of harmless resistant organisms.

"The calcium hypochlorite process of sterilizing water combines the desirable qualities of economy and efficiency, and affords cities and towns which are unable financially to build a filtration plant, but are forced for sanitary reasons to adopt some method of purification, a means of ensuring a safe water-supply. It may be used to advantage in cases of emergency, where either filtered or unfiltered supplies have become infected and where it is difficult to cease using such supplies. Where mechanical filtration is not sufficient to render a water safe, treatment with calcium hypochlorite offers an excellent method of sterilization and is especially applicable in such cases."

What has just been stated regarding the use of the hypochlorites may also be said concerning chlorine gas,

and since marked improvements have been made in the apparatus for utilizing this gas for this purpose in recent years, it has largely supplanted the hypochlorites and is being very widely used both for the treatment of raw or unfiltered waters and as an added safeguard to those that have been filtered. One advantage in addition to that of its high sterilizing efficiency is that of its relative cheapness, "it costing an average of three cents per 100,000 gallons treated."

That the employment of this method is extensive throughout the country is manifest by the following assertions from probably the largest manufacturers of chlorinating apparatus: "Over 3000 American municipalities now safeguard their drinking water supplies by chlorination. This represents 65 per cent. of the population of North America." Also, "nearly 80 per cent. of the drinking water supplied to North America is sterilized with liquid chlorine and it is estimated that 70 per cent of the people drink chlorinated water."

Moreover, apparatus can now be had not only for municipalities, both large and small, but also for sterilizing swimming pools, the drinking water of summer hotels and camps and of lake and ocean steamers, the wash-water of milk stations, etc.; so that this process apparently already supplies a widely distributed protection against the water-borne diseases.

Filtration.—For the purification of large quantities of water, such as are needed for great cities, there can be no question that sand filtration is, in the majority of cases, the most available, satisfactory, and efficient method, though it may often be advantageously preceded by sedimentation or by chemical treatment, as already described. The former especially, by removing much of the suspended matter, will prolong the use of the filters between cleanings and thus materially lessen the cost of maintenance; while the latter may greatly improve the chemical quality of the filtered water.

Municipal filters of the type to be described have been

used abroad with increasingly good results for upward of half a century, and many are already in use in this country and now furnish the daily supply of water to millions of

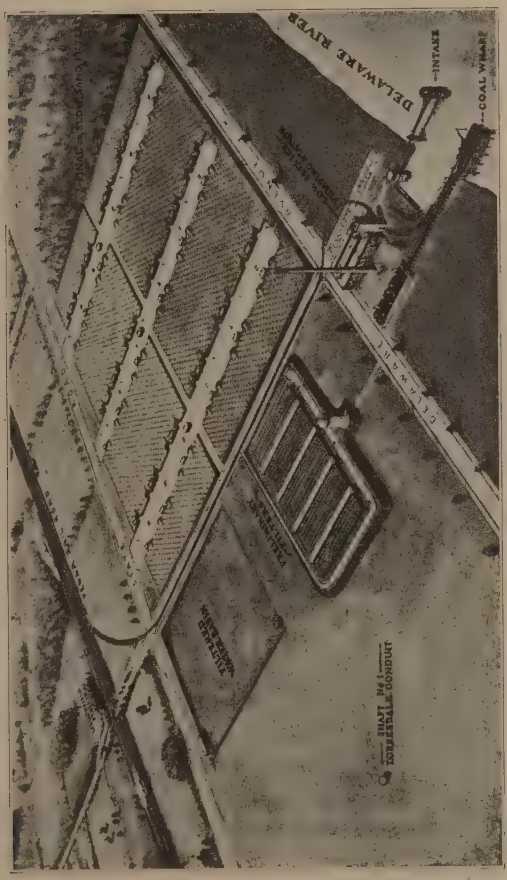


FIG. 63.—Torresdale filter station. (Philadelphia Bureau of Water, description of the filtration works and pumping station, 1909.)

people. We may take credit in the knowledge that the most thorough and scientific investigation of their action and efficiency has been made on this side of the Atlantic, under the auspices of the Massachusetts State Board of Health, and that it is to this body that we are indebted for much of the positive information that we now have concerning them.

The limitations of this work do not permit a full discussion of the principles or merits of such filters, but the following details are given that the reader may appreciate

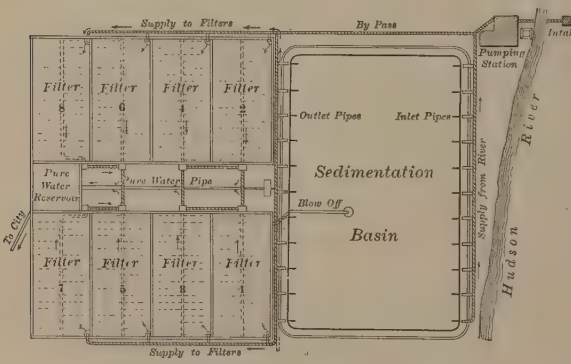


FIG. 64.—Plan of filter-beds at Albany, N. Y.

the simplicity of their construction and the efficiency of their action. Those desiring more extended information are referred to the Massachusetts reports that discuss this subject, and to the excellent work of Hazen, already mentioned,[1] from which many of the accompanying statements and illustrations have been taken.

Almost without exception these filters now consist of a layer of clean sand of a certain degree of fineness spread upon a layer of gravel in a carefully prepared basin, the whole being underdrained and proper arrangements made

[1] Filtration of Public Water Supplies.

for the controlling of the depth of water upon the surface, rate of flow of the filtrate, cleaning of filters, etc. Such filters act primarily as strainers, to remove the solid impurities from the water, but their efficiency is much increased by the sediment that is retained upon the surface of the sand and that forms a filter or "blanket" much finer than the latter and which is capable of mechanically preventing the passage of most of the bacteria always present in a surface-water. Moreover, this removal of the bacteria is often largely due to the organisms themselves in the sediment-layer, because by forming a felt-like growth therein they not only increase the fineness of the strainer, but by acting as saprophytes they also decompose much of the organic matter and even kill the

FIG. 65.—General arrangement of filter-plant. (Hazen.)

pathogenic bacteria. However, it now seems probable that for continuous filters the action is sometimes mainly mechanical, consisting in the removal of suspended matters and bacteria, and but slightly affecting the dissolved organic matters. On the other hand, in intermittent filtration, where the conditions more nearly resemble those in the natural soil and where the filters are periodically aërated, the straining action is less perfect on account of the greater rate of filtration necessary, but the nitrification and destruction of organic matter due to the action of the saprophytes and oxygen are greater. Intermittent filters, therefore, will probably prove to be the better for the purification of sewage or a very impure water, though usually their efficiency in removing bacteria seems to be inferior to that of continuous filters.

The location of the filter-beds with respect to the source of supply and the storage reservoirs will depend largely on local conditions, cost of pumping, etc. Settling basins are almost essential where the water to be filtered is very turbid, even if only at intervals. Reference has already been made to the difference of opinion between English and Continental authorities regarding the size of these settling basins.

Inasmuch as it is needful to govern the depth of the water upon the filter-beds according to the rate of flow desired, the thickness and resistance of sand, etc., and to prevent disturbance of the sand and sediment layer by

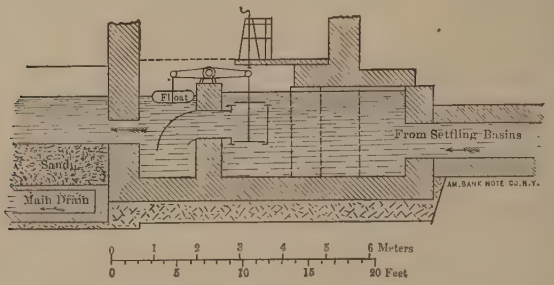


FIG. 66.—Regulation of inflow used at Hamburg. (Hazen.)

the force of the entering current, some method of regulating the inflow is required. The accompanying illustration shows a comparatively simple arrangement for this purpose. (Fig. 66.)

The total area of the filter-beds will depend upon the amount of water supplied, the rate of filtration, and the proportion of area out of use while being cleaned. The total area is to be divided into beds, varying in number according to circumstances, so that one or more of these beds may be cleaned while the rest are in use. Large beds decrease the cost per acre on account of less masonry,

etc., being needed, but it may be more difficult to maintain an even action over large areas. At the Torresdale filtration plant in Philadelphia, which is the largest in

Fig. 67.—Interior of a covered filter ready for use.

the world, and has a capacity of 240 million gallons of filtered water per day, the area of each of the sixty-five

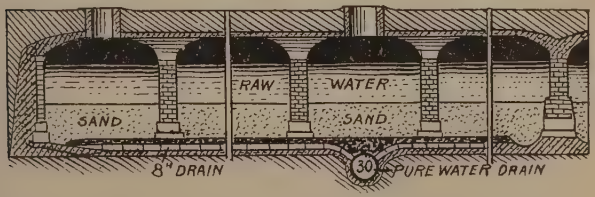


Fig. 68.—Sectional plan of a covered filter.

slow sand filters is approximately three-fourths of an acre, and the individual area of the beds at the other

filtration stations of that city vary from this to a little more than one-half acre. Evenness of action is, however, largely governed by the size and arrangement of the underdrains.

The walls and bottoms of filter-beds should be made water-tight, that there may be no waste of the filtered water on the one hand, nor any ingress of foul soil-water on the other. The shape of the filter-bed is immaterial, provided evenness of work over the whole area is not impaired, Where the mean January temperature is below the freezing-point the beds should be covered, as the formation of ice upon them seriously impairs their efficiency, and as, moreover, a number of epidemics of typhoid fever and certain intestinal diseases seem to be directly traceable to ice-formation. This may have been on account of the overtaxing of the filters through increased difficulty in working, or because the sediment layer and the sand were disturbed in the removal of the ice.

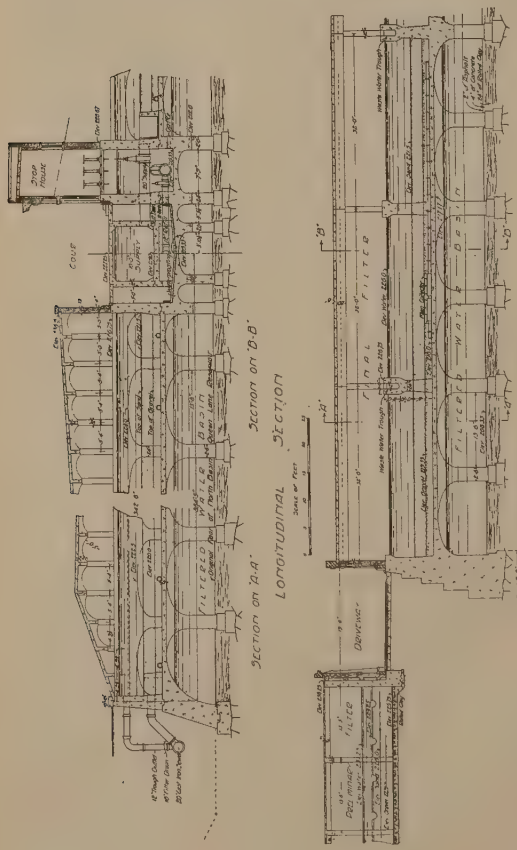
As already stated, the materials used practically everywhere are clean sand and gravel, and the sharper the sand-grains the better. At the Lawrence Experiment Station of the Massachusetts State Board of Health "the size of a sand-grain is uniformly taken as the diameter of a sphere of equal volume, regardless of its shape." Moreover, as it is "the finest portion which mainly determines the character of sand for filtration," the *effective size* is taken to be "the size of a grain such that 10 per cent. by weight of the particles are smaller and 90 per cent. are larger than itself." As uniformity of grain is also important, the *uniformity coefficient* is "the ratio of the size of grain which has 60 per cent. of the sample finer than itself to the size which has 10 per cent. finer than itself." Obviously, the velocity of water through a layer of sand will depend upon the effective size of the grain, the thickness of the layer through which the water passes, and the loss of head due to the frictional resistance of the sand. A rise in temperatures causes a progressive increase in velocity.

The effective sizes of sand-grain in use in most of the foreign filters average from 0.31 to 0.4 mm. In general, it may be said that the finer the sand the better is the quality of the normal filtrate and the less the danger of an unsafe effluent in case the sediment layer on top of the sand is broken; but, on the other hand, cost of filtration increases with the smallness of sand-grain, since the filters must be cleaned oftener and fine sands are harder to wash, as well as because the velocity of flow is slower through fine sands. All things considered, the best results will probably be obtained with a sand having a uniformity coefficient of not more than 3—the lower the better—and an effective size of from 0.2 to 0.35 mm., the latter depending largely upon the character and clearness of the water to be filtered.

The thickness of the sand layer should be such that it may be scraped a number of times before becoming so thin as to require replacing. The German Imperial Board of Health requires a thickness of at least twelve inches after the last scraping; while the original thickness should be from twenty-four to forty-eight inches—the thicker the better—provided the cost of the filter be not made too great and the rate of filtration be not too much diminished. The sand should be of the same degree of fineness throughout.

As for the gravel beneath the sand, there is no reason why it should be of excessive thickness. A depth of one foot is probably sufficient, provided the stones are of varying size, so arranged that the sand above will not work into and through the interstices, and that the water may freely enter the underdrains at low velocity. The loss of head in water flowing through a thin layer of gravel properly placed is comparatively slight. Foreign filters do have a gravel layer of two feet or more in thickness, as a rule, but careful experiments at Lawrence, Mass., show that this depth is unnecessary, provided that the gravel is properly laid as indicated, and that the underdrains are not too far apart.

The underdrains should be of such size and so constructed that the frictional resistance which they offer to the flow of the water is only a small percentage of that of



Queen Lane Filters. Sections.

FIG. 69.—Filter beds over storage reservoirs. (Philadelphia Bureau of Water. Description of the filtration works and pumping stations, 1909.)

the clean sand, and that the rate of filtration is the same over the whole area of the filter. There is usually a main drain along the middle of the filter-floor with smaller parallel lateral drains leading into it at regular intervals. The drains may be made of brick with open joints, or, for the laterals, of tile, which is usually cheaper. Care must always be had that the openings are sufficient in number and size to admit the water freely.

The area drained should vary from about 300 square feet for a 4-inch lateral drain to 4400 square feet for a 12-inch main, the velocity of flow in these being respec-

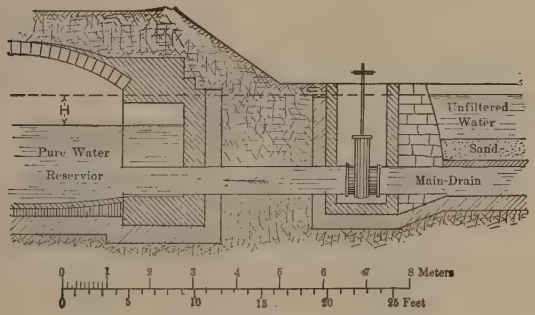


FIG. 70 —Simplest form of regulating outflow from filter-beds. Stralau filters at Berlin. (Hazen.)

tively 0.3 and 0.51 foot per second; while larger drains should have a cross-section of at least one-six-thousandth of the drained area. The European custom of ventilating drains by means of pipes passing up through the sand and water above is not to be commended, since such ventilation apparatus is unnecessary, increases the cost of the filters, and, what is worse, may allow impurities to contaminate the filtered water in the underdrains.

Recently it has been suggested that the filter-beds be constructed directly over the storage reservoirs for the

filtered water, the beds being supported on suitable columns resting on concrete foundations in the bottom of the reservoirs. The bottom of the filter may be of impervious concrete, as it is in the Queen Lane filter in Philadelphia, or pervious to allow the filtrate to be aërated as it falls through the intervening space above the water in the reservoir below. Theoretically, it would seem that the latter plan is a good one, and actual results indicate that it practically is so. Some of its advantages are the absence of underdrains and loss of the resistance factor due to them, the aëration of the filtrate as indicated, and also the practically continuous aëration of the filter-bed itself, thus enabling the saprophytic bacteria in the upper layers to carry on their work of oxidizing and nitrifying the organic impurities of the water. One serious objection to such a filter is that an accidental overflow would contaminate at once all the filtered water in the storage reservoir. An additional advantage of either type is the utilization of former sedimentation reservoirs that are supplanted by the filters, especially where economy of space is desirable or sufficient adjacent area is unobtainable or too costly.

Although it has been the custom to keep the depth of water upon the filter-beds in excess of the loss of head, this is not essential. On foreign filters the usual depth is from 36 to 52 inches, though less than this might suffice in many instances. The necessity of regulating the inflow and outflow and of maintaining a constant level must not be overlooked if uniform results are desired.

Summarizing the preceding statements, the loss of head and rate of filtration will depend upon the depth of water on the filters, the thickness of the sand layer, size of sand-grains, resistance of underdrains, temperature, etc., and all these will likewise affect both the cost and the efficiency of the filtration.

Where the water is taken directly from a river, or if the opportunity for sedimentation has been brief, 3,000,000 gallons per acre per day will probably be a safe rate of

filtration to maintain continuously, though with a clear water or in emergencies a rate one-half greater will very likely not materially alter the quality of the filtered water or increase the risk. But in general as the rate increases the efficiency decreases. However, very careful and thorough experiments preliminary to the construction of the Philadelphia filters and practical experience since, have shown that in the case of some waters, at least, the rate may safely be increased to even 5,000,000 and sometimes to almost 6,000,000 gallons, provided the water be first passed through a sedimentation basin and

FIG. 71.—Sand ejector in service. (Philadelphia Bureau of Water, description of the filtration works and pumping stations, 1909.)

a so-called "preliminary" or "rough filter" made of such materials as crushed furnace slag, coke breeze or coarse sand or gravel. In the latter much of the suspended matter that has passed through the sedimentation basin will adhere to the innumerable surfaces of the coarse and porous material constituting the "preliminary filter," thus lessening the load and prolonging the action of the real filters through which the water now passes. The "preliminary filters" are cleaned by agitation, washing and removal from time to time of the contained materials.

As the sediment accumulates and deepens upon the surface of the sand the rate of flow necessarily diminishes, and it becomes necessary after a time to remove the deposit. This may be done by carefully scraping off the top layer of the sand to the depth of from one-half to one and one-half inches, removing the sand to platforms outside the filter and thoroughly washing it with a stream of filtered water under pressure or by passing it through one or more sand washers. The sand need not be replaced

FIG. 72.—Nichol's sand separator in operation. (Philadelphia Bureau of Water, description of the filtration works and pumping station, 1909.)

immediately, for the filter may be scraped a number of times before the layer of sand above the underlying gravel becomes too thin. The accumulation of sand on the washing platforms, which has been exposed to the action of the sunlight and air, is then carefully replaced, packed, and levelled upon the beds. These do not again attain their greatest efficiency until a certain amount of sediment from the water has once more collected upon them, and it is therefore not advisable to use the filtered water for some time after the cleaning and until bac-

teriological tests show that the maximum purification is being attained.

To economize in manual labor, the sand may be transported to the washing platform or the sand washers by means of a sand ejector whereby the sand is carried by a forcible stream of water supplied through a line of fire hose, the sand being partially cleansed while in transit. By the use of a sand separator the sand may be cleaned without removing it from the limits of the filter-bed. The separator consists of a closed steel cylinder with a cone-shaped bottom, and within which is arranged a system of baffles and a disc. The sand is forced into this from the sand ejector, there being a down-flowing stream of sand and an up-flowing stream of wash-water so proportioned that no sand is lost in the wash-water, which is carried away from the top of the separator and out of the filters to the sewers, while the cleaned sand is discharged from the bottom and distributed through a hose on top of the filter-bed where it is spread and levelled by manual labor.

An essential in the management of all large filters is the daily bacteriological and chemical examination of both the filtered and unfiltered water. This not only serves to give warning of any accident to the filter, but is necessary, as the best test of the efficiency of a sand filter is the percentage of bacteria which it takes from unfiltered water. Unless a filter is holding back from 98 to 99 per cent. or more of the bacteria, it needs close inspection, although it must be remembered that it is more difficult to get good results with a badly polluted water than with one that is comparatively pure. The presence of the colon bacillus in the filtered water demands additional effort and care, or, perhaps, subsequent chemical treatment with calcium hypochlorite or chlorine. In Philadelphia the addition of one-half pound of chlorine to one million gallons of filtered water (*i. e.*, 1 part in 16 millions) seems to entirely eliminate all trace of this organism.

Mechanical Filters.—Where a water contains a very fine sediment or silt in large quantities, the sand-bed

may be clogged and choked in a few hours and before there is time for the formation of the bacterial film mentioned above; therefore, the filtration must be more mechanical. For example, at New Orleans, where the Mississippi River contains an enormous amount of a silt so fine that much of it is submicroscopic and many of the particles even smaller than bacteria, the water is pumped from the river to a sedimentation basin capable of holding twenty-four hours' supply, through which it passes slowly, leaving the coarser and heavier sediment; then to a mixing basin, where alum is added as a coagulant to an extent not exceeding six grains per gallon, and then to the sand filter-beds. The "blanket" is thus formed by the coagulum due to the alum which commingles with and holds the silt, preventing the latter from entering and choking the filter. The filter-beds are cleaned daily or oftener by forcing from below first a liberal washing of filtered water and then a supply of air. The cost of this treatment is about $600 per day for a supply of 40,000,000 gallons.

As the filtration does not remove hardness due to dissolved minerals, it may also be advisable to use the Clark process previous to sedimentation and filtration. Part of the color due to peat or vegetable matters is removed by ordinary filtration, and still more may sometimes be destroyed by the previous addition of alum, but such preliminary treatment for this purpose is unusual. Where the water comes from a lake or from a river with a slow current, settling basins are, of course, unnecessary, but any chemical treatment of the water prior to filtration practically implies the use of mechanical instead of slow sand filters because the action of the chemicals necessarily destroys or eliminates the saprophytic bacteria which are so essential to the proper action and efficiency of the slow sand filter.

Mechanical filters consist essentially of large cylindrical vats or tanks (containing rather coarse sand or crushed quartz through which the water passes by gravity or is forced by the pressure in the supply main much more

rapidly than through the type already described. Alum commonly is used as a coagulant to form a precipitate which entangles and retains the suspended matter, including microörganisms and other particles of the smallest size, and which thus does the work of the bacterial "blanket" of the slow sand filter. "Ferrous sulphate and lime may be advantageously used in certain special cases, but all coagulants possess the power of gathering together the finer particles

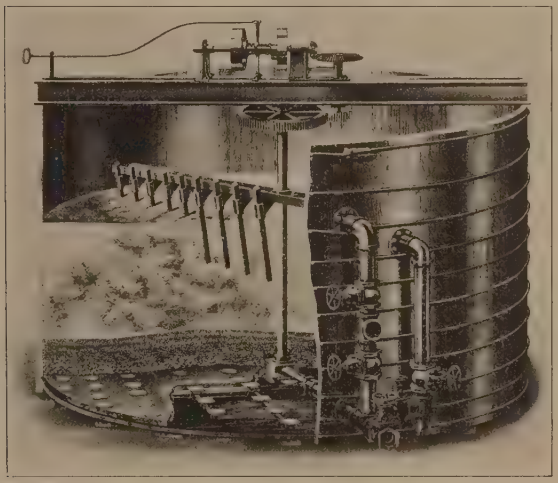


FIG. 73.—Mechanical filter, showing revolving forks or rakes, and also the system of strainers below through which filtered water is forced upwards to cleanse the filter-bed. (Courtesy of Hungerford and Terry.)

of matter into comparatively large masses so that sedimentation proceeds at a very rapid rate." The supply of alum must, of course, be proportioned to the amount of suspended matter in the water, being delivered in solution through regulating valves to a mixing tank or to the filter vats directly. The accumulated precipitate and sediment must be removed at comparatively short intervals, as the filters soon clog and the supply of filtered

water rapidly lessens. The cleansing of the filters is accomplished by forcing a reverse current of filtered water from the bottom of the tank while the sand is at the same time thoroughly stirred by forks on revolving arms driven by machinery; hence the term "mechanical."

"The coagulant must be fed with extreme accuracy. If a deficiency is used, the desired results are not attained. If an excess is used, the chemicals are not all decomposed and free sulphate of alumina becomes present in the filtered water." A small amount of this in the water may not be important as regards human consumption, but may be so in certain commercial processes, such as dyeing, etc. Such filters are probably not quite as efficient in purification and are usually more expensive to maintain than the slow sand filters, but with certain waters this type only can be used effectively.

DOMESTIC PURIFICATION OF WATER.

Boiling destroys living organisms and disease germs; it also drives off the carbon dioxide and other gases of the water and causes the precipitation of many mineral substances held in solution by these gases. This is especially the case, as has been stated, where the water is hard from the presence of calcium bicarbonate in excess; but iron is also often thrown down by boiling. If the water contains a very fine sediment, not removed by settling or filtration, it may be advantageous to add a little alum and chalk to produce the flocculent precipitate already described. Potassium permanganate has little effect in purifying a foul water. Agitation with iron filings may do a little good by favoring oxidation of organic matters. Tannin is believed to destroy microörganisms, and a harmful water may sometimes be made usable by boiling with tea-leaves or other astringents. Citric acid is said to destroy algæ and many kinds of bacteria. Aëration and agitation improve a water after distillation or boiling by restoring oxygen and also by oxidizing organic matters. Remember that boiled

water is prone to take up gases of any kind, whether impure and offensive or otherwise. Organic matters are removed by boiling, exposure to air, agitation, addition of alum, astringents, charcoal, etc.; calcium bicarbonate, by boiling or by adding caustic or slaked lime or a little sodium hydroxide or sodium carbonate; iron, by boiling and by adding lime-water. According to Parkes and

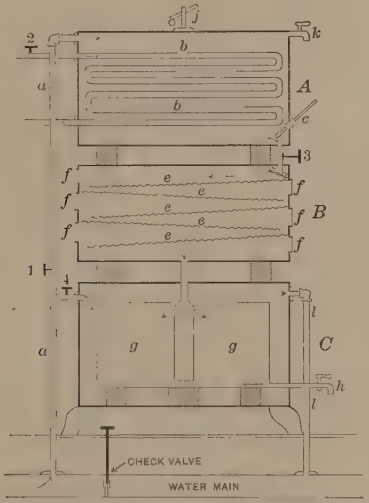


FIG. 74.—Water sterilizer for schools, factories, etc.:[1] *a*, Supply pipe; *b*, steam coil; *c*, thermometer; *e*, *e*, corrugated and perforated metal plates; *f*, *f*, air openings guarded by cheese-cloth; 4, tap to admit cooling water around *g*, *g*, the storage tanks.

Rideal, fifteen grains of acid sodium sulphate to the pint (1 in 500) will destroy typhoid bacilli in five minutes. Calcium and magnesium sulphates and chlorides cannot readily be removed. Some plants help to purify by means of the oxygen which they give to the water.

[1] From the Bulletin of the Chicago Health Department, Sept. 19, 1903.

Distillation gives, of course, a water free from harmful impurities, but one which has lost it gases, and which may be improved in palatability by aëration or by being charged with carbon dioxide gas. Stills for domestic use, capable of supplying an abundance of water for drinking and cooking purposes, can now be purchased at moderate cost. The main objection to distillation in the household is that the process is somewhat slow and tedious.

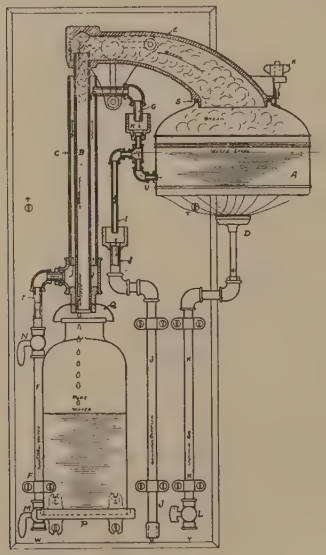


FIG. 75.—Section of domestic still.

An apparatus which furnishes a boiled water free from disease germs, yet unchanged in taste by the boiling, and at nearly the same temperature as the water entering the apparatus is the Forbes (formerly the Waterhouse-Forbes) sterilizer. The principles involved in its con-

struction and operation are that only a small bulk of water is being boiled at any instant; that it is boiled

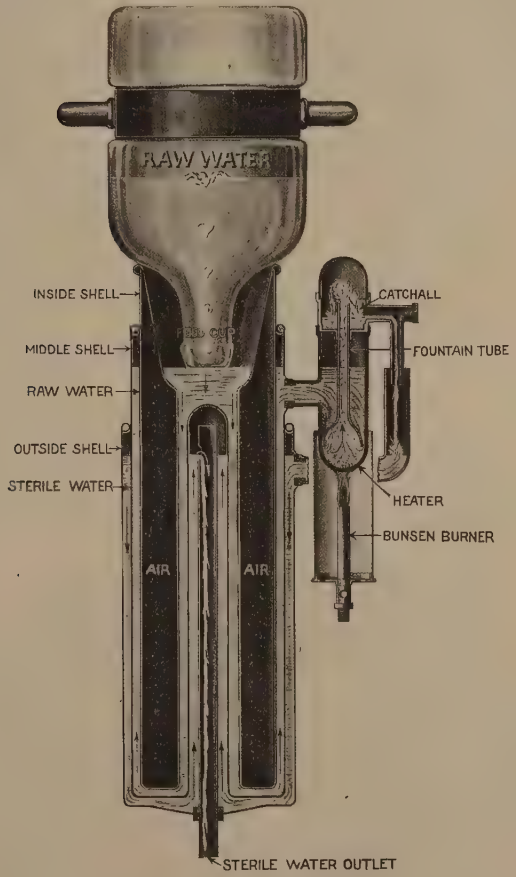


FIG. 76.—Forbes's sterilizer.

for only a very short time, thus preventing loss of the original gases and taste; that all disease germs are killed by the boiling; that it is impossible for water which has not been boiled to pass through the apparatus; and that the heat of the boiled water is used to warm the unboiled water (thus economizing fuel) at the same time that the latter is made to cool the former.

This apparatus is furnished in a suitable size for household use. It is also made on a large scale and in a convenient form for transportation, having been adopted by the United States Army shortly after the Spanish-American War, as being "well adapted to the abundant supply of sterile water for troops in the field."

In recent years the use of the above-described sterilizer has been superseded in the U. S. Army by the Lyster water-bag which is more convenient for transportation, and by means of which, advantage is had of the sterilizing effect of calcium hypochlorite. For dwellings or permanent stations, however, the Forbes sterilizer remains an excellent device for securing a safe water-supply. A Lyster bag is one of canvas, holding about 40 gallons, with loops at the top for suspending it and several self-closing push-cocks at the bottom for drawing the water after sterilization.

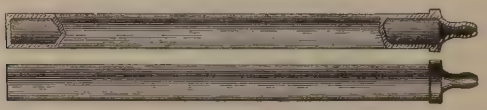


Fig. 77.—Tubes of unglazed porcelain for Pasteur-Chamberland filter.

House filters are dangerous unless properly cared for and may give more and worse impurities to the water than they take from it. What a filter takes from a water is left in the filter unless otherwise removed, and an accumulation of such impurities cannot improve the water passing through them. The organic matters will undergo decomposition and putrefaction, and will furnish a good culture-medium for bacteria, and these, together with the soluble putrefaction-products, will in most cases be carried

through the filter with and by the filtered water. A filter has no miraculous power to annihilate filth and the size of a filter must always limit the work it can do, whatever the materials used.

According to Parkes, the requisites of a good filter are: (1) That every part shall be easily accessible for cleansing or renewing the medium. (2) That the filtering medium shall have sufficient purifying power and be present in sufficient quantity. (3) That the medium give nothing to the water favoring the growth of low forms of life. (4) That

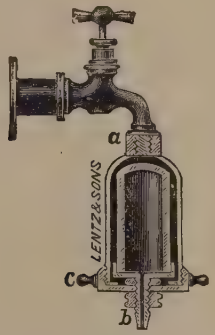


FIG. 78.—Berkefeld filter attached to tap.

the purifying power be reasonably lasting. (5) That there be nothing in the construction of the filter itself capable of undergoing putrefaction or of yielding metallic or other impurities to the water. (6) That the filtering material shall not clog, and that the flow of water be reasonably rapid; to which may be added: (7) That the filtering medium be such that it can be readily cleansed and sterilized, or else so cheap that the removal and replenishing may not be neglected, when necessary, on account of the expense.

House filters may be divided into three classes: (*a*)

those entirely disconnected from the water-supply pipes of the house; (*b*) those connected with the water-pipes, but intended to filter only a limited quantity, as for drinking, cooking, etc.; (*c*) those connected with the house

FIG. 79.—Pasteur-Chamberland filter with reservoir for filtered water.

service-pipe and intended to filter all the water used in the house. The same filtering media may be used in all three classes, but it will be found best in the first two to employ substances through which the water passes slowly, while the latter class must necessarily filter the water more

rapidly in order to yield a sufficient supply. It will often be advantageous to have a settling tank connected with

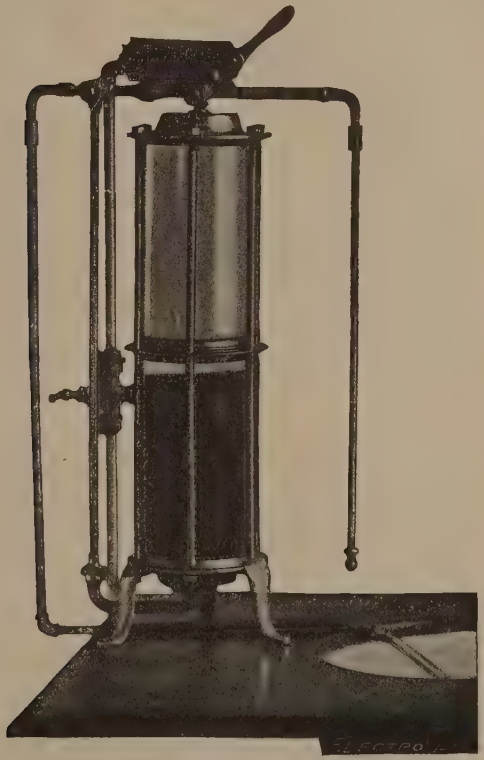


FIG. 80.—Glass model of Loomis-Manning filter, showing filter in action.

those of the first class, to prolong the safe use of the filter as long as possible; while the same object is gained in some of the second class by bringing the water in at the bottom,

in which case there should be a space below the filtering medium to allow the suspended matters to fall away from

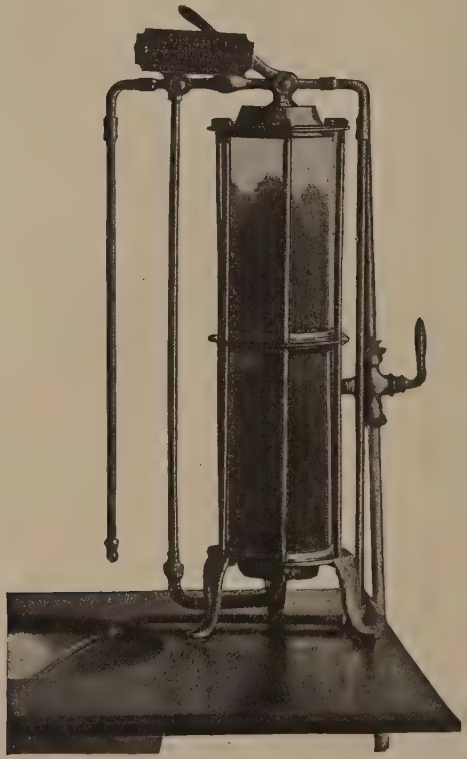


FIG. 81.—Glass model of Loomis-Manning filter, showing self-scouring of material during cleansing.

the latter. Those intended to filter the whole supply of the house are generally cleansed by reversing the current

and washing the collected dirt out of the filter into a drain or sewer, the first water passing through the filter after this is done being also discarded. In such filters the quantity of filtering material should be sufficient to purify thoroughly the water passing through it, and yet should not be so heavy that the reverse or washing current cannot lift it and separate the particles so that by their scouring action upon one another they may be cleansed and all the dirt washed out. These filters also may be so arranged that a small quantity of a coagulant, such as alum, is automatically added to the water before filtration. If this be done, care must be had to supply no more of the coagulant than suitable tests show to be necessary, else the excess may be carried through the filter in solution.

No matter what kind of filter is used, the drinking-water should always be boiled in times of epidemics or when the water before filtration is especially impure; for, though the Berkefeld, the Pasteur-Chamberland, and a few other filters are practically bacteria-proof, there always remains a possibility that disease germs may by some means pass through the filtering medium or gain access to the water after it is filtered. The writer's own opinion is that there is a saprophytic or biological action in most good filters that are regularly and frequently cleaned very similar to that which takes place in filter-beds on a large scale, and that ordinarily few, if any, bacteria pass through with the water; but, nevertheless, the risk should not be taken if there is danger of incurring disease at any time.

Filters in which the material is cemented up so that it cannot be removed for cleaning or renewal should not be used. Sponge, wool, etc., are liable to decompose and give organic matter to the water and, moreover, cannot be thoroughly cleaned. Asbestos acts only as a mechanical filter and may allow albuminous matter and disease germs to pass. Asbestos-cloth may be used, however, to support the other filtering media in those filters where the water-supply enters at the bottom, and it has the advantage that it can be perfectly sterilized by fire. Small tap

filters are insufficient for the work required of them and soon clog. Pocket filters are simply strainers, and have

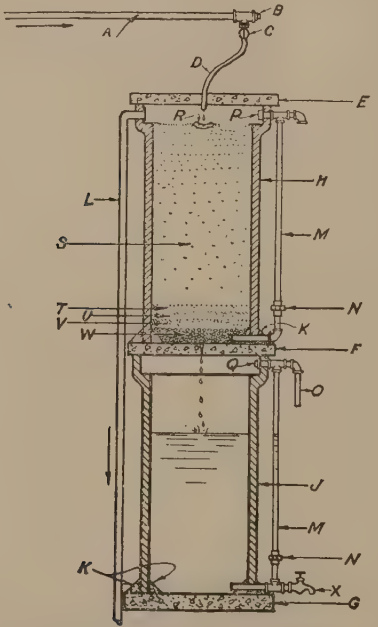


FIG. 82.—Home-made slow sand filter. Capacity, 25 to 30 gallons per twenty-four hours and costs about $10. *A*, supply pipe; *B*, brass tee, plugged; *C*, brass pet cock; *D*, rubber tube; *E*, concrete cover; *F*, concrete slab with cone-shaped hole $\frac{1}{16}$ inch in diameter at the bottom of the slab in the center; *G*, concrete base slab; *H*, *J*, 10-inch vitrified pipe, each 2 feet long; *K*, water-tight cement fillet; *L*, overflow, $\frac{1}{2}$-inch lead pipe; *M*, $\frac{1}{2}$-inch glass tube; *N*, $\frac{1}{2}$-inch union; *O*, $\frac{1}{2}$-inch vent and overflow; *P*, tight cap; *Q*, nut, pipe open; *R*, piece of slate, brick or tile; *S*, clean fine sand; *T*, 1-inch layer of coarse sand; *U*, $\frac{1}{2}$-inch layer of gravel size of shot; *V*, $\frac{3}{4}$-inch layer of gravel size of a pea; *W*, $1\frac{1}{4}$-inch layer of gravel about $\frac{1}{2}$-inch size; *X*, $\frac{1}{2}$-inch brass faucet for drawing filtered water. (Water Systems for Farm Homes, U. S. Department of Agriculture, *Farmers' Bulletin*, p. 941.)

little oxidizing power. They may be quite useful for tourists, hunters, etc., but should be frequently sterilized by boiling. Ordinarily, filters should not be placed in rain-water cisterns, but outside, where they may be readily cleaned.

Among the best filtering media are sand, animal charcoal, magnetic carbide of iron, spongy iron, etc. Unglazed porcelain or bisque, as is used in the Pasteur-Chamberland filter, is an excellent medium, and is practically germ-proof, though some observers state that bacteria will pass through uncleaned filters of this material after five or six days of use. Others claim that these are not bacteria, but only the mycelia of certain budding fungi, with no power of reproduction, and the former statement seems to have been positively disproved with respect to the germs of typhoid fever, colon bacilli, and similar organisms. The tubes of the Berkefeld filter are made of diatomaceous earth, molded into shape by powerful hydraulic pressure, so that the water percolates through the pores of the minute fossil shells rather than between them. If kept clean, these give good service, but it has been recently stated that typhoid bacilli will pass through them after several days. Stone filters may be good, and resemble the porcelain ones in action, but are apt to be slow and must be cleaned often. Sharp, clean sand, not too fine, has fair filtering properties, as it arrests most of the suspended matters and bacteria, beside oxidizing somewhat the dissolved organic matters. It makes a good first layer for a filter, because it is cheap and can be easily renewed or else readily cleansed and sterilized by boiling. Crushed quartz is of practically the same nature.

Animal charcoal is, when fresh, an excellent material, as it removes both suspended and dissolved matters, organic and inorganic, and even color. It acts both mechanically and chemically, and with a good volume of it water may pass through rapidly and be well purified. But after a time it ceases to be effective; nor must water be left too long in contact with it, as it will give up

organic matter to the water again and also calcium phosphate, the latter especially favoring the development of micro-organisms. Moreover, fresh organic matter, and possibly bacteria, are said to pass through it readily, though dead or decomposing matter is retained and rapidly destroyed. It should be changed or cleansed, even when in sufficient bulk, three or four times a year; oftener if the water to be filtered is very impure. It is more efficacious than any other substance in removing lead from water.

Magnetic carbide of iron is one of the best filtering materials, as it has considerable power in oxidizing organic matters, converting them into nitrates and nitrites, the action being greater the longer the water is in contact with it. It acts partly by surface condensation of oxygen; partly, perhaps, by electrolytic action. If sand be used as a first layer to remove solid matters so that the water reaches the carbide perfectly clear, and if the sand be frequently renewed or cleansed, the carbide need never be changed; but the filtration must be intermittent so that the carbide may be frequently aërated. Spongy iron has an action very similar to that of the magnetic carbide on organic matters, and, like it, the action is the greater the longer the contact. It must be kept covered with water to prevent rusting and caking, and should be renewed about once a year. The small amount of iron that the magnetic carbide and spongy iron give to the water may be removed by passing it through a layer of pyrolusite—a crude magnesium oxide. A mixture of pyrolusite and sand or crushed quartz makes an excellent filtering material.

Regarding house filters, the following caution from a Government bulletin is worthy of notice.[1] "A filter is a device for removing dirt from water. It promotes purity and safety, but never is a guarantee. It does not excuse the use of water taken from sources known to be con-

[1] Farmers' Bulletin, No. 941, U. S. Department of Agriculture: Water Systems for Farm Homes.

taminated. Filtration alone does not materially affect such dissolved matters as the water may contain. If, for instance, brine be filtered, the resultant will be salt water. Not only must the accumulated dirt be removed from filters according to their use and the dirtiness of the water filtered, but the filtering material must be cleaned, aërated or sterilized from time to time. Dirty sand can be washed, but dirty charcoal must be replaced with new charcoal four or five times a year. Charcoal filters, if neglected, may become a detriment rather than a benefit, due to the storage and overloading of organic matter within the pores and upon the surface of the charcoal."

In recent years other methods for purifying water, both in large and moderate quantities have been devised, the various agencies employed being electricity, ozone, ultra-violet radiations, etc.; but although some of these methods, at least, seem fairly well perfected, their use is still somewhat in the experimental stage and not sufficiently general to warrant more than a brief mention in a work of this kind.

Ice should not be added to filtered or drinking-water, as freezing, even for a long time, may not kill certain disease germs. Prudden has kept typhoid bacilli frozen in ice for more than three months without destroying their power of growth and reproduction when brought to a suitable temperature. The same objections do not, of course, pertain to artificial ice carefully made from distilled water as to that from polluted ponds or rivers; but it is well to cool the water by placing it in stoppered bottles upon ice or in vessels surrounded by ice rather than by adding the ice to the water directly.

The inadvisability of using ice-water freely as a beverage should be mentioned here, as the habit is almost certain to cause much harm to the digestive apparatus, and to give origin not only to intractable dyspepsias, but to troubles even more serious. If used at all, ice-water should be taken slowly and in small quantities, and as

little as possible should be imbibed at meal-time, in order to prevent chilling of the stomach and consequent checking of the digestion. Its use and the liking for it are mainly a matter of habit which it is hygienic wisdom to overcome.

EXAMINATION OF DRINKING-WATER.

The examination of a drinking-water should have regard to its physical, bacterial, and chemical properties as well as to a consideration of all the conditions affecting its source, storage, and distribution. Consequently, a decision on the purity of water should be governed by all the available knowledge of the circumstances: whether it is well-water, spring-water, rain-water, or river-water; whether it has been at any time exposed to pollution; in what kind of a cistern or reservoir it has been stored, etc.

A physical examination of water considers the color, clearness, sediment, lustre, taste, and smell. Pure water has a bluish tint, but most waters are grayish, greenish, yellow, or brown. Yellow or brown waters are subject to suspicion, as the color may be due to animal matter or sewage, though vegetable matters or iron may give the same color. Green waters are usually harmless, the color being due to vegetable matters. The color is judged by allowing the sediment to settle and then siphoning or pouring off the supernatant water into a tall glass vessel or tube to the depth of about twenty-four inches; the color is then compared with that of a similar depth of distilled water, looking down through both upon a white surface.

The clearness of a water is to be estimated in the same way, except that the sediment is to be shaken up with the water. The depth needed to obscure print of a certain size and kind of type may be used as an index. Where the solid matter will not readily settle, owing to the minuteness and lightness of the particles, one should determine whether the use of a coagulant and filtration is

indicated, or whether boiling will tend to precipitate the sediment. The sediment may be roughly judged by the eye as to whether it is mineral or otherwise; it should also be examined microscopically, for which purpose it may be collected by using a centrifugal apparatus or by allowing it to settle from the water in a conical glass and then removing it to the slide with a pipette. Mineral matters are recognized by their crystalline or amorphous structure or by microchemical tests; vegetable cells, portions of leaves, etc., by their structure and the presence of chlorophyll; animal substances, as hair, wool, epithelial and other cells, by their peculiar characteristics. Dark brown, globular masses may come from sewage. Anything indicating that water has come from human habitation renders it suspicious, as it may therefore contain sewage or other polluting substances. Some of the larger animalculæ and sometimes iron may be detected with the naked eye.[1]

The lustre is supposed to indicate the amount of aëration; it may be *nil*, dull, vitreous, or adamantine. It should not be forgotten that a very impure water may be clear, bright, and sparkling.

Any water of peculiar or unpleasant taste should be considered with suspicion. Dissolved animal matters may be tasteless, but suspended substances give a peculiar taste, whether animal or vegetal. Iron is about the only ordinary mineral that can be tasted in small quantities. Good water depends for its taste mainly upon its gases, and water free from gas tastes flat.

The smell of a water, if it has any, may be brought out by heating gently to about 110° F., or by boiling it. This may make evident a fecal odor, although hydrogen sulphide may mask this latter; in such a case the sulphide may be removed by adding a little cupric sulphate to the water. The odor may also be developed by allowing the water to stand in a stoppered bottle in a warm place for a few days.

[1] See J. C. MacDonald's Guide to Microscopic Examination of Drinking-water.

A bacteriological analysis is almost as necessary as a chemical one, for purity in the one respect does not necessarily indicate purity in the other. The presence of *Bacterium coli communis* in a water, irrespective of any pathogenic organisms, would create more than a suspicion of contamination by fecal matters, as this microbe is practically a constant occupant of the human intestinal tract.

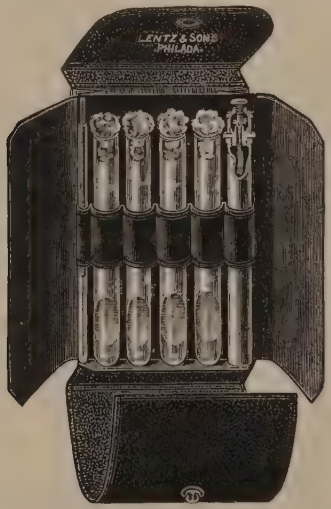


FIG. 83.—Pocket-case containing sterilized culture-tubes, platinum needle, and alcohol lamp, used for obtaining cultures for diagnosis, etc.

But water may be capable of carrying typhoid or other infection and yet be free from colon bacilli, since the disease germs may have been introduced into the water from urine rather than feces.

Water may be collected for bacteriological analysis in sterilized, closed bulbs blown from glass tubing. The heat used in sealing the ends creates a partial vacuum

within the bulb, so that if the tip of one end be broken off beneath the surface of the water, the latter is drawn into the bulb, which can then be resealed and conveyed to the laboratory. But as some of the bacteria may multiply rapidly in transportation and as some species may even destroy others, it is always best, if possible, to inoculate the tubes of sterilized culture-media at the place where the supply for examination is obtained. Or one may add a small quantity of the water to melted nutrient gelatin at the time when the samples are taken and make plate cultures in the manner already described. The number of colonies resulting therefrom will indicate practically the number of bacteria in the volume of water added to the gelatin.

The details of some simple but fairly accurate tests and methods employed in the chemical analysis of drinking-water will be given in another chapter. Here we need only consider the influence that the substances sought for in the analysis have in affecting potability, and within what limits we may consider them as being permissible in drinking-water. The water should be filtered or free from sediment for all the tests, except in the estimation of nitrogen as ammonia compounds and as organic matter, and of the oxygen-consuming power of the water.

The amount of total solids will vary with the source of the water, and much more may be present in some cases without risk of harm than would be safe in others; but usually the proportion should not exceed 50 or 60 parts in 100,000. Only a small portion should be volatile, and there should be little charring on ignition, except in the case of waters from peaty soils; nor should there be any odor on ignition, especially of ammonia compounds, as that would indicate an excess of animal organic matter. Deep well-water will probably have much more total solids than rain-water or clear river-water, the excess being mainly mineral substances dissolved from the strata through which the water passes.

Even the purest waters contain a little chlorine, usually in the form of sodium chloride; but, as the latter is a constant constituent of household slops and sewage in general, any excess of chlorine above the amount common to the water of the district, unless otherwise accounted for, will be decidedly suspicious, and sewage contamination should be looked for. So, also, any sudden increase in the proportion of chlorine would very likely indicate the accession of some new source of contamination to the water. Unless accounted for by the strata traversed or by the locality, more than 3 parts of chlorine in 100,000 of water is very suspicious.

The presence of considerable "free ammonia" in rain-water is not a bad sign, as it has probably been absorbed from the air; but the same amount in subsoil-water, especially if with an excess of chlorine, would indicate probable contamination with urine, as the latter rapidly undergoes ammoniacal putrefaction. In such a case there will probably also be considerable "albuminoid ammonia," but much albuminoid ammonia with little free ammonia and chlorine generally indicates vegetable contamination. The writer is acquainted with a case in which, although the water is pure and from an unpolluted source, the albuminoid ammonia and chlorine are in marked excess, the former being altogether of vegetable origin—from a peaty soil—and the latter characteristic of the whole district, which is near the sea-coast. The free ammonia is, however, slight in amount. An excess of free ammonia, chlorine, nitrates, and nitrites indicates animal contamination, though, if the pollution be by effluvia alone, there may be no excess of chlorine.[1] The total ammonia in a usable water should not be over 0.13 or 0.15 part per 1,000,000. If there is almost no "free" ammonia, the "albuminoid" may amount to 0.1 part per 1,000,000 without giving cause for suspicion; likewise, if there is but little "albuminoid," there may be considerable "free" ammonia; but if the "albuminoid" exceeds 0.05 part

[1] Kenwood's Hygienic Laboratory, p. 49.

per 1,000,000, the "free" must not be greater than this proportion. The simplest test for ammonia is by means of Nessler's reagent—a solution of a double iodide of potassium and mercury. It gives a yellow or yellowish-brown coloration when ammonia is present.

Organic matters of animal origin, and therefore nitrogenous, are during oxidation partially converted into ammonium compounds, and these, by the action of certain bacteria, may be further oxidized into nitrites and nitrates. "Nitrification takes place under the influence of microbes, the habitat of which does not extend more than a few yards below the surface of the soil. The nitrifying action is probably exerted only upon the ammonium which is formed from the organic matter. The presence of some substance capable of neutralizing acids is necessary to continuous action. Calcium and magnesium carbonates fulfil this function. Nitrates are the final result of this action; nitrites are present at any given time only in small quantity."[1] Deep water may, of course, also contain nitrates taken up from strata rich in these salts.

Although nitrites and nitrates are not harmful in the quantities usually found in water, and though the water containing them may have been thoroughly purified by natural filtration through the soil, their presence, as will be seen from the above remarks, is important in determining the character of the water. The presence of the slightest trace of nitrites is always suspicious, and any marked amount of nitrates, excepting possibly in a deep water, should require close investigation; the nitrates and nitrites together measured in terms of nitrogen should not exceed 1 part per 1,000,000.

The hardness should not be greater than that indicated by 20 or 30 parts of chalk in 100,000, and the more "temporary" in proportion to the "permanent" hardness the better.

Phosphates, not from phosphatic strata, help to indicate

[1] Leffmann and Bevan, Examination of Water, 2d edition, p. 13.

sewage contamination. So, also, do sulphates, though these by themselves may come from unimportant sources.

It will be seen from the above statements that the opinion regarding any water must be based on a broad consideration of all the circumstances in relation to it, and not from the presence or absence in it of any one or two substances which are not in themselves harmful. The presence of poisonous metals above the limits of safety, however, would alone contra-indicate the use of a water. For instance, there should not be more than 0.04 grain of lead or copper, 0.25 grain of zinc, or 0.5 grain of iron to the gallon in any water, and the faintest trace of arsenic condemns it.

The following table has been adapted from Parkes:

CLASSIFICATION AND PROPERTIES OF VARIOUS WATERS.

Class.	Physical.	Microscopic.	Chemical (parts per 100,000).
I. Pure water.	Colorless or bluish tint; transparent, sparkling, and well aërated; no sediment visible; no smell; taste palatable.	Mineral matter; vegetable endochrome; large animal forms; no organic débris.	Chlorine under 1.4 Total solids under 7.14 Ammonia under 0.007 Nitrogen, as nitrites and nitrates, and in albuminoid ammonia, under 0.023 Total hardness 8.05
II. Usable water.	Colorless or slight greenish tint; transparent, sparkling, and well aërated; no suspended matter, or easily separated by coarse filtration or subsidence; no smell; taste palatable.	Same as for pure water.	Chlorine under 4.3 Total solids under 42.8 Ammonia under 0.015 Nitrogen, as nitrites and nitrates, and in albuminoid ammonia, under 0.125 Total hardness 17.03
III. Suspicious water.	Yellow or strong green color; turbid; considerable suspended matter; no smell, but any marked taste.	Vegetable and animal forms, more or less pale or colorless; organic débris: fibers of clothing or other house refuse.	Chlorine 4 to 7 Total solids 43 to 71 Ammonia, 0.015 to 0.023 Nitrogen, as nitrites and nitrates 0.124 to 0.237 Total hardness above 17.0
IV. Dangerous water.	Yellow or brown color; turbid, and not easily purified by coarse filtration; large amount of suspended matter; any marked smell or taste.	Bacteria of any kind; fungi; numerous vegetable or animal forms of low types; epithelia or other animal structures; evidence of sewage or ova of parasites, etc.	Chlorine above 7.14 Total solids 71.4 Ammonia above 0.0225 Nitrogen, as nitrites and nitrates, above 0.242 Total hardness above 28.05

CHAPTER VIII.

FOOD.

The use of food is necessary to build up the body-structure, to repair waste, and to furnish force and energy for the proper action of all the organs, tissues, and parts of the body. In addition, certain substances are needed, not so much because they become a part of the tissue framework or yield kinetic energy directly, as that they are essential factors in the multitudinous chemical reactions and changes that are continually occurring within the living person. We may, accordingly, define a food as anything that tends to fulfil any one of these functions, provided it is not at the same time by nature harmful to the economy, and that it does not produce physiological effects out of proportion to its nutritive or metabolic activities.

Strictly speaking, this definition might include air and water, as the former is necessary to supply oxygen for union with other foods or with the tissues themselves, and the latter is needed to assist in the solution and assimilation of foodstuffs, to maintain the fluidity of the body-juices and to moisten the tissues effectively, to preserve roundness of form, and to flush out and remove from the system those waste matters and excrementitious substances whose retention gives rise to the symptoms of certain autogenetic diseases. But they are not usually included in the category of foods, and, having already been considered, they may be passed over in this connection with but incidental reference here and there.

If we classify foods according to their chemical composition, we may separate them, or rather the food-principles, into the following main divisions: (1) Proteids and albuminoids; (2) Carbohydrates; (3) Hydro-

carbons or fats; and (4) Salts, extractives, etc. Each group is subject to different digestive and metabolic processes, and each has usually a different office within the body; for experience and careful experiments both show that all of these different food-principles are needed to sustain life and maintain health for any considerable length of time, and that they are thus the chief essentials of food; although what are sometimes called the accessory foodstuffs and many pleasant volatile odors and flavors are desirable and advisable adjuncts to the food proper, since they greatly favor its reception, digestion, and assimilation. But, though each class of food has its own special function in the economy of nutrition, in times of need or deprivation any one of the first three divisions may, in a way, supply the place of either of the other two.

"Recently it has been suggested that beside the foodstuffs in the ordinary sense, other constituents of our food exist which are of the very greatest importance for life."[1] To this latter class of substances, whose lack seems to interfere with growth and to cause emaciation and certain diseases, the term *vitamines* has been applied, although it must be said that the term is not well chosen, as they are not members of the *amine* group and as the above-mentioned food principles are equally essential to life.

Fothergill[2] epitomizes the use of the food-principles in this way: "The carbohydrates are the body-fuel, the surplusage being stored as fat; the albuminoids (proteids) serve to repair the tissues as they wear out; the salts form the blood-salts; the fat helps to build up normal health tissues, the excess being burnt as body-fuel. That is the real object of food."

While in the main correct, this is a broad statement of facts, and it needs qualification. For instance, just

[1] Text-book on Physiological Chemistry, Hammarsten and Hedin-Mandel, 1905, 7th ed.

[2] Manual of Dietetics, p. 5.

as there is some wear and tear in any mechanical machine while in use which must eventually be provided for, so in the human body with its manifold activities there must be some destructive effect upon the body-structure and tissue framework, and it is to renew and replace this inevitable loss of material that a part—perhaps the larger or greater part—of the proteid food is taken. But we also know that in addition to this simple repair and replacement of tissue, "the presence of nitrogenized structure, and its participation in the action going on there, is a necessary condition for the manifestation of any vital energy or any chemical change," and we have reason to believe that, entirely apart from the idea of repair, proteid food is essential to the development and maintenance of this chemical and vital activity of nitrogenized tissue.

Confirming this, Pettenkofer and Voigt have shown that the absorption of oxygen is largely determined by the nitrogenous substances composing the tissues of the body, and that it is proportional to their size and vigor. Moreover, it is known that proteids may be, in part, converted into fat and possibly into other oxidizable substances, and thus become a source of body-heat and energy.

So, also, with the fats and carbohydrates. While they are not immediately nor entirely interconvertible, and while neither class may be permanently excluded from the diet, yet in emergency either may apparently fully supplant and substitute the other for a time, and we cannot yet say exactly how similar or dissimilar their service within the body is.

However, while Fothergill's epitome needs this emendation, known facts make it comparatively easy to gain a fair idea of the differences and functions of the proximate food-principles, to which end some help will probably be given by the following table:[1]

[1] Notter and Firth, Treatise on Hygiene, p. 257.

Properties and Functions of Food-principles.

	Examples.	Functions.
Nitrogenous Substances.		
1. Proteids.		
All substances containing nitrogen of a composition identical with or nearly that of albumin; proportion of N to C being nearly as 2 to 7 or 4 to 14.	Animal: Albumin, Fibrin, Syntonin, Myosin, Globulin, Casein. Vegetable: Glutin, Legumin.	Formation and repair of tissues and fluids of the body. Regulation of the absorption and utilization of oxygen. May also form fat and yield energy under special conditions. In most foods the above, both animal and vegetable, are largely converted into albumoses and peptones.
1 (*a*) Substances containing a larger proportion of nitrogen are apparently less nutritious. Proportion of N to C about 2 to 5½ or 4 to 11.	Gelatin, Ossein, Chondrin, Keratin,	These perform the above functions less perfectly, or only under particular circumstances.
1 (*b*) Extractive matters, such as are contained in the juice of the flesh.	....	These substances appear essential as regulators of digestion and assimilation, especially with reference to the gelatin group.
Non-nitrogenous Substances.		
2. Fats (*or Hydrocarbons*).		
Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the proportion of oxygen being *less* than sufficient to convert all the hydrogen into water. Proportion of unoxidized H to C, about 1 to 7.	Olein, Stearin, Margarin,	Supply of fatty tissues; nutrition of nervous system; supply of energy and animal heat by oxidation.
3. Carbohydrates.		
Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the oxygen being exactly sufficient to convert all the hydrogen into water. Proportion of water to carbon, about 3 to 2.	Starch, Dextrin, Cane-sugar, Grape-sugar Lactin (or milk-sugar)	Production of energy and animal heat by oxidation; form fats and possibly some proteid.
3 (*a*) *Vegetable acids* (*and pectous substances*). Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the oxygen being generally in greater amount than is sufficient to convert all the hydrogen into water.	(More O than is sufficient to convert all H into H_2O.) Oxalic acid, Tartaric " Citric " Malic " (No excess of O.) Acetic acid, Lactic "	Preserve the alkalinity of the blood by their conversion into carbonates; furnish a small amount of energy or animal heat by oxidation.
4. Salts (*mineral*).	Sodium chloride, Potassium chloride, Calcium phosphate, Magnesium phosphate, Iron, etc.	Various; support of bony skeleton, supply of HCl for digestion, etc. Regulators of energy and nutrition.

DIETETICS.

Dietetics means "the branch of medicine or hygiene that treats of diet and dieting," and its study includes "a systematic regulation of the diet for hygienic or therapeutic purposes." It considers all the factors that affect the proper digestion and assimilation of food. For instance, it is not alone necessary to determine just what substances, in a chemical sense, the body needs to sustain life and maintain health. Nor is it sufficient to say that a man must have just so much of this and so much of that food, for there must always be a variation in both kind and quantity to meet the changing demands of the system. With a few exceptions, no matter how toothsome or healthful a certain food may be, it soon palls upon the appetite if necessity compels its continued use for a prolonged period, and this disgust may be so impressed upon the memory of the senses as to cause them to object to the use of that food forever after.

The esthetic factors in the preparation and serving of food must also be taken into account, and the success in pleasing the taste and appetite has much to do with the progress and completeness of digestion. Other things being equal, palatable and agreeable foods are disposed of much more satisfactorily than others not so, and physicians and others should learn that especially in sickness the appearance and palatability of a food have much to do with its acceptance, not only by the patient, but by his stomach as well. Cleanliness and neatness of food, china, and napery are of greater value than expense or show, and a little attention and tact in such matters will often enable a patient to take, enjoy and retain food and receive nourishment, even when he or she asserts and believes this to be impossible.

Another factor of much importance in the digestion of food, but one too often too lightly considered, is the mood or state of mind when the food is taken and while it remains in the alimentary canal. There is more than

moral philosophy in maintaining a cheerful and a tranquil disposition during the daily meals and for a time thereafter; while there are numerous instances of most serious results occurring from the giving way to anger or other intense emotion at such times, the digestive functions being either completely checked, or, what is frequently worse, so altered that their products are toxic in character. And is not a dyspeptic often so because of his pessimism, rather than a misanthrope because of his indigestion?

Before proceeding further it will be well to consider briefly the physiology of digestion in so far as it concerns the chemical changes occurring in the food while it is in the digestive tract. These changes are brought about by the action of certain bodies secreted or elaborated by the digestive organs and glands, which we have been in the habit of calling unorganized ferments, but which would, perhaps, better be known hereafter as *enzymes*. Unorganized ferments are so called because they have not the definite cell-formation, life, and power of reproduction which belong to the yeasts, mould-fungi, and bacteria which bring about the fermentative changes in organic substances so commonly within the knowledge of everyone, such as the conversion of saccharine solutions into alcohol, of alcohol into acetic acid, etc.

But though unorganized, the enzymes likewise act upon organic matter; for example, upon the food which we eat, and—like the other ferments—they apparently do this simply by their presence rather than by entering into actual combination with the matter acted upon, as do ordinary chemical reagents. They are undoubtedly the products of glandular protoplasm, probably proteid in nature, and some, at least, very likely belonging to the group of nucleo-albumins, which latter form a component part of every organic cell.

The comprehension of the digestive functions will be greatly simplified if the student remembers that, "with the possible exception of the coagulating enzymes, the action

of the enzymes is that of hydrating agents: they produce their effect by what is known as *hydrolysis*—that is, they cause the molecules of the substance upon which they act to take up one or more molecules of water; the resulting molecule then splits or is dissociated, with the formation of two or more simpler bodies."[1]

Thus the insoluble proteids and carbohydrates become respectively the soluble amino-acids and sugars of their allies, capable of being absorbed into the myriad capillaries that are distributed throughout the lining membrane of the alimentary tract. Even the change that takes place in fat when digested is one that involves the taking up of some water.

There are four characteristics of the enzymes worthy of note: (1) That they are all soluble in water and glycerin, the latter being especially useful in making stable preparations of them from the organs producing them. (2) "That very low temperatures (0° C.) retard or suspend entirely their action, without, however, destroying the enzyme; that for each enzyme there is a temperature at which its action is greater," and that "in a moist condition they are all destroyed by temperatures below the boiling-point; 60° to 80° C. are the limits actually observed."[2] (3) "That they never completely destroy the substance upon which they act," probably being retarded by their products when the latter reach a certain percentage. "When these are removed, the action of the enzymes begins again." (4) "Except for very small quantities, it may be said that the amount of change caused is independent of the amount of enzyme present;" or, rather, "with increasing amounts of enzymes the extent of action also increases, reaching a maximum with a certain percentage of enzyme; increase of enzyme beyond this has no effect." The amount of work capable of being done by a small proportion of an enzyme is enormous, good pepsin, for instance, having the

[1] American Text-book of Physiology, 1st edition, p. 219.
[2] Ibid.

power of converting 2500 times its own weight of proteid; but we must remember that this power is not infinite, and that after a time the enzymes will cease to act.

There are five groups or classes of enzymes concerned with the proper digestion of food to be found in the animal body, and it is interesting to note that examples of each of these classes are also to be found in various members of the vegetable world. The two principal remaining classes, being neither of animal origin nor digestive agents, need only be mentioned here: they are the *glucoside-splitting* and *urea-splitting* enzymes, the latter being produced by certain bacteria and converting urea into ammonium carbonate.

Considering the digestive processes in their order as the food proceeds from the mouth through the alimentary canal, we find that the first active secretion or fluid is the saliva, and that its enzyme is *ptyalin*, belonging to that group which converts the insoluble carbohydrates (starches) into soluble sugars, maltose, etc. Ptyalin acts best in neutral or slightly alkaline media, at about the body-temperature (40° C.), and upon cooked much better than upon raw starch.[1] Its action is retarded or totally checked by a low temperature or by strongly alkaline or moderately acid solutions, and the enzyme itself is probably destroyed by an increase in acidity equal to that of the gastric juice, or by a temperature of 65° or 70° C. The reason it converts cooked starch so much more quickly is probably because the heating process breaks up the cellulose envelopes upon which the ptyalin has almost no effect and which protect the starch granules within from its action. The heat also causes a very close union

[1] Kubel claims to have found that an alkaline reaction, even when very weak, actually interferes with ptyalin digestion, but that it is favored by a weak acid reaction, especially if the acid be one of the stronger ones like HCl. He admits that an amount of hydrochloric acid equivalent to that of the gastric juice checks the activity of the ptyalin, but believes that at the beginning of a meal and for a time thereafter salivary digestion takes place better in the stomach than in the mouth. (Boston Medical and Surgical Journal, April, 1899.)

between the molecules of starch and water, this facilitating the later hydrolysis by the enzyme.

In addition to its digestive function, the saliva also serves to moisten dry food so that it may be swallowed, and to dissolve sapid and savory substances that they may be duly appreciated by the organs of taste.

Our first hygienic lesson in regard to the digestive functions is, therefore, that in order to get the full benefit of the salivary secretions, all food, and especially that of a starchy nature, should be well masticated and retained in the mouth for some little time, instead of its being "bolted" at once or after a hasty bite or two. Evidence is also at hand that with proper mastication there will be little danger of overeating, and, in most cases, a decided decrease in the consumption of proteids, the latter probably resulting in a lessening of fatigue products and an increase in endurance.

Nor should very cold or very hot beverages be taken at the same time with food, for not only will the action of the ptyalin be thus retarded or destroyed, but that also, as we shall see, of the gastric juice within the stomach. A note here as to the drinking of water at meal-time will not be out of place. A moderate quantity of proper temperature will probably be beneficial rather than otherwise, since it helps in the solution of the food; but an excessive quantity tends to harm by diluting the enzymes too much, thus interfering with their reactions, and by interfering with the absorption of the digested matters. Moreover, it has been shown that not only does the saliva act best when diluted with about three times its volume of water and provided the food has been thoroughly masticated, but also that water is a positive excitant of both the gastric and pancreatic secretions.[1]

The food, having passed from the mouth to the stomach, may still be acted upon for a time by the ptyalin until the work of the latter is checked by the acid of the gastric

[1] See Physiology of Alimentation, Martin H. Fischer, pp. 104, 226, and 232.

juice.[1] The energy of digestive action is then transferred from the starches to the proteid constituents of the food, the chief enzyme now being *pepsin*, though we also find in the gastric juice a coagulating ferment—*rennin*—which acts upon soluble proteids, like the casein of milk, to form clots or curds.

Pepsin acts only in an acid medium (the acidity being supplied normally by the free hydrochloric acid of the gastric juice), and best at the body-temperature. As stated, extremes of temperature are adverse to its activity and may check it altogether, and, likewise, too much or too little acid may have the same effect, from 0.2 to 0.3 per cent. of HCl being the normal amount and giving the best results. Rennin[2] seems in the normal stomach to act only on the casein of milk, and curdles this probably because it is then more easily digested by the pepsin and, later, by the trypsin of the pancreatic juice.

The action of the pepsin, plus the acid, upon the proteids of the food is a hydrolytic one, and the end-products are practically hydrated proteids, called albumoses and peptones. The gastric digestion, therefore, after the action of the ptyalin has been checked by the acid gastric juice, practically has to do only with the albuminous or nitrogenous part of the food, the remainder remaining unchanged until it passes further on into the intestines. Soluble

[1] Recent experiments seem to show that "ptyalin digestion normally continues during the first hour of gastric digestion, or, in fact, until the hydrochloric acid secretion reaches the normal maximum." (A. L. Benedict, Journal of the American Medical Association, July 28, 1900.) Grützmer has also shown (Pflüger's Archiv, 1905, cvi, 436) that the reaction within the main mass of the food in the stomach may remain alkaline or neutral for some two hours, the digestion of proteids by pepsin going on only at the pyloric end and in that part of the food that is in contact with the stomach walls.

[2] Oppenheimer says concerning rennin: "It does not appear to have any essential significance for the digestion of proteids. It is strikingly absent in the newborn, who consume much milk. Zuntz and Sternberg have even found that milk proteid coagulated by rennin is less easily digested than the original milk proteid, and attributed to this in part the relatively smaller availability of milk for adults, who produce more rennin." (Torald Sollmann, Journal of the American Medical Association, February 9, 1907, p. 521.)

sugars, and part at least of the water imbibed, may, however, be taken up by the stomach capillaries, while the rest of the food-mass, kept ever in motion by the muscular movements of the stomach-walls, is being thoroughly mixed and converted by the peptic action into the semiliquid substance called chyme, which is passed at intervals and in small quantities through the pyloric opening into the duodenum.

Long before the stomach has entirely emptied itself—which may only be after several hours of activity[1]—intestinal digestion is well under way, and in some respects this is the most important as well as the most comprehensive process of all. The three secretions to whose combined action the chyme is now subject are the pancreatic juice, the bile, and the intestinal juice. All are alkaline and quickly neutralize the gastric acid; it scarcely need be noted, then, that the remaining enzymes act best or only in alkaline media, though one of them, trypsin, may act in solutions not too strongly acid.

In the pancreatic juice we find three enzymes, practically the only remaining ones of much importance; although in the rather scanty intestinal juice two others have been found, one capable of converting starch into sugar and the other of inverting cane-sugar into levulose and dextrose. The bile contains no enzymes. The pancreatic ferments are *trypsin*, which acts upon proteids and albuminoids even more powerfully than pepsin, and which also converts the resultant albumoses and peptones into amino-acids, the end products of proteid digestion; *amylopsin*, which is practically identical with ptyalin in its function; and *steapsin*, which causes neutral fats to take up water and split into free fatty acids and glycerin.

Under the action of the trypsin, aided by *erepsin*,

[1] "Cannon and others have shown that the main mass of the food remains in the stomach for a considerable time—three hours with a carbohydrate meal, six hours with a proteid meal, twenty-one hours with a fatty meal. A portion of the food leaves the stomach much earlier." (Torald Sollmann, loc. cit., p. 522.)

another ferment secreted by the intestine, all that portion of the proteid food which has not been completely digested in the stomach reaches that stage in the small intestine and is absorbed therefrom. In fact, it is very probable that the tryptic digestion is often the more important of the two. As the action of the saliva upon the carbohydrates, which form the greater bulk of our food, must of necessity be comparatively limited, it is evident that most of the starch digestion is performed by the amylopsin, aided in slight measure by the similar enzyme of the intestinal juice. The salts and other soluble elements of the food having already been absorbed, there remain only the fats or hydrocarbons to be considered.

Under the influence of the steapsin a comparatively small portion of the fat in the food is separated into glycerin and free fatty acids, and this action for some reason takes place much more rapidly when aided by the bile than with the pancreatic juice alone. Then these fatty acids unite with the alkalies and alkaline salts of the above secretions, but especially of the bile and intestinal juice, to form *soaps*, and these soaps aid the steapsin in emulsifying the remainder of the fats and in thus making them ready for absorption, which latter process is also facilitated by the direct action of the bile upon the intestinal epithelium.

The student must not get the idea that the absorption of digested food from the alimentary canal is merely a physical process and a simple matter of osmosis or diffusion. Accumulating experience indicates that it is in a measure, if not largely, vital and physiological, and that "the living cells of the intestinal wall appear to take an active share in the process, and modify the action of the physical factors in a manner not at present understood." This is probably especially true as regards the absorption of the fats, whether we take the commonly accepted view that most of the fat is emulsified and only a small portion split up and saponified in the intestine, or the one which some have advocated of late years, viz., that almost, if

not all, of the fat is decomposed and dissociated, and comparatively little, if any, emulsified.

The digestive processes having thus been outlined, it will be well to learn how they may be maintained as complete and perfect as possible. In the first place, the cooking of food is usually an essential preliminary. We cook meats not only to make them more agreeable to the palate, but also to facilitate digestion. The effect of cooking upon muscle (flesh) is "to loosen the bundles of fibrillæ from each other, so that they are readily torn asunder or crushed by the teeth," while the various connective tissues are softened and gelatinized, not only thus becoming more digestible and nutritious, but also allowing the histological elements which they bind together to separate and be more freely acted upon by the solvent fluids. So with the vegetables, the heat and steam soften and rupture the cellulose envelopes of the various cells that the ferments may the more readily act upon their contents; and at the same time they bring about subtle chemical changes that greatly increase the palatability of the foodstuffs.

Thorough mastication of the food is important for the reasons already stated, and the cause of most dyspepsias may be found in faulty habits of eating. Foster says that in the stomach "the natural bundles of meat and vegetables fall asunder, the muscular fibres split up into disks, and the protoplasm is dissolved from the vegetable cell;" but, "if the meat be not chewed properly, but 'bolted,' the solvent gastric juice can only act on the exterior of the mass, while 'lumps' offend the stomach and arrest the gastric secretion." "Coarse particles of food also delay the opening of the pylorus, and so keep a meal in the stomach a correspondingly longer time."[1] The importance of abstaining at meal-time from beverages or other substances of too low or too high a temperature

[1] Physiology of Alimentation, Fischer, p. 14.

has already been noted, and, as all the enzymes act best at the body-temperature, care should always be had to avoid chilling of the abdominal organs while digestion is under way.

Again, as the formation and action of the enzymes begin with the ingestion of food and depend largely upon a sufficient blood-supply to the organs concerned as long as digestion continues, it is essential that the blood-current shall not be diverted from these organs during this period by excessive mental or physical demands, and that a condition of cheerfulness, repose, and rest should prevail during and following every meal. Regularity as to the time of meals and the avoidance of too great a tax upon any of the organs by overindulgence or intemperance in eating or drinking are likewise both important matters and ones too often neglected.

It is interesting to note that in certain members of the vegetable kingdom are to be found enzymes very similar to the normal ones of animal origin just considered, and that where the latter appear to be deficient in quantity or action these kindred ones may sometimes be used with advantage. Thus, in the pineapple and in the papaw are ferments akin to pepsin or trypsin, and in the former another with the same action as rennin. All are familiar with the diastase of germinating seeds and its use in the making of malt; but not so common is the knowledge that other seeds contain fat-splitting enzymes much like steapsin. But though these and other extraneous digestants may be valuable and advantageous as therapeutic agents when an actual lessening or cessation of normal function makes them necessary, a caution should be interpolated here regarding the habit that may be acquired of depending too much upon them, especially by persons, otherwise healthy, whose digestive functions are somewhat deficient. A better plan is to bring those functions up to the normal in strength and vigor by the observance of hygienic rules and a well-considered method of life.

THE AMOUNT OF FOOD NECESSARY TO LIFE AND HEALTH.

Considerable work has been done to determine just what amount of the proximate food-principles the average person requires daily, and in this respect Moleschott's tables are quite generally accepted, having been constructed from data gained by actual experiment and also by the continued observation of the effects of a number of dietaries. According to these tables, a man weighing 160 pounds and doing work equivalent to 300 foot-tons per diem will need about 4.6 ounces of proteids, 3 ounces of fats, 14.25 ounces of carbohydrates, and a little more than 1 ounce of salts. Vaughan believes that the average working-man in America requires daily, in round numbers, not less than four ounces of proteids, two ounces of fats, and eighteen ounces of carbohydrates. Chittenden has recently claimed that four ounces of proteids is considerably more than is necessary to maintain health, but the quantities given are the ones generally accepted by physiologists.

It is essential that the proper proportion between the ingested nitrogen and carbon should be maintained, and this should be as *one* of the former to *fifteen* of the latter.

In addition, the individual needs from 70 to 100 fluid-ounces of water daily, a good part of which, however, is normally taken with the food. It must be remembered that the above figures represent only average amounts, and that climate, amount of exercise, the size and activity of functional and excretory organs, and personal peculiarities all serve to modify them in the case of any special individual.

Other conditions not interfering too greatly, any combination of foods giving the above amounts of the proximate principles at a reasonable cost will be an economical and healthful diet, provided such food is acceptable to the palate, is digestible, and contains nothing harmful to the system, and that it include the essential accessory sub-

stances or so-called vitamines that recent research seems to prove necessary to health and well-being.[1]

Since a large portion of food that is eaten goes for the production of heat and energy, the nutritional needs of the body may appropriately be measured in terms of these physical manifestations of force. The unit of measurement of the quantity of heat energy is the calorie, which is the exact amount necessary to raise 1 kilogram of water 1° C. in temperature, this being almost equivalent to raising 1 pound of water 4° F.

With this unit, accordingly, not only has the amount needed by the body at different ages and for various degrees of activity been carefully determined experimentally, but also the caloric values of many articles of food more or less commonly used. Thus, for the average adult at rest about 1600 calories per day are needed simply for the vital functions, to which must be added anywhere from 1000 to 3000 or more extra calories to supply the energy for the activities of daily life. Children because of their very active metabolism, require relatively more units than adults, a fact that should not be lost sight of in planning a family dietary or one for a school, camp or any group of youngsters.

AVERAGE CALORIC REQUIREMENTS FOR CHILDREN OF VARIOUS AGES.[2]

Years.	Calories per day.
1 to 2 (children)	1000 to 1200
2 to 5 (children)	1200 to 1500
6 to 9 (children)	1400 to 2000
10 to 13 (girls)	1800 to 2400
10 to 13 (boys)	2300 to 3000
14 to 17 (girls)	2200 to 2600
14 to 17 (boys)	2800 to 4000

It is also well to have some knowledge of the relative caloric values of the respective foods in common use in

[1] For such combinations, see Vaughan's Healthy Homes and Foods for the Working Classes; and Mrs. Abel's Practical, Sanitary, and Economic Cooking. Both are essays published by the American Public Health Association.

[2] Winslow and Williamson: The Laws of Health, p. 60.

order that one may be able to select his diet intelligently, both as regards the satisfaction of his physical needs and as to its cost. Where economy is important, as in arranging a family dietary or where food must be purchased for large numbers of individuals and slight differences make large totals, an article of low cost may be of equal or higher value than one priced higher, or, on the other hand, the higher-priced one may be the more economical to purchase of the two.

This, however, does not mean that it is necessary or wise to portion out each meal to an exact measure of calories or to adjust the day's food supply to a definite maximum or minimum. In fact, many students of this subject feel that too much importance has been given to this matter of caloric values in comparison with that of determining the relative quality and physiological benefit of various foods and their probable influence upon the health and welfare of the consumers. This is especially a matter of serious concern in the feeding of infants and young children. A food might contain the full quota of caloric units desirable, and yet be absolutely inadequate or detrimental because of its content of inadvisable proteins or lack of essential salts, vitamins, etc.

It is interesting to note that "so far as the United States is concerned, according to Raymond Pearl, 91 per cent. of our total calorie supply is derived from the following nine foodstuffs and 70 per cent. of it from the first four on the list."[1]

Foodstuff.	Percentage of total.
Wheat	26
Pork	16
Dairy products	15
Sugars	13
Corn	7
Beef	5
Oils	4
Potatoes	3
Poultry and eggs	2

[1] Winslow and Williamson: The Laws of Health, p. 60.

"Liberal consumption of all of the essential constituents of a normal diet, prompt digestion and absorption and prompt evacuation of the undigested residue from the intestine before extensive absorption of products of bacterial decomposition of proteins can take place, are the optimum conditions for the maintenance of vigor and the characteristics of youth."[1]

Fothergill thinks that, as a rule, we take too much proteid food, especially in the form of meat, and that, though this goes in the main for tissue-repair, the latter requires much less of such food than we ordinarily suppose, and that the system does not need so very much of albumen or its equivalents. In this he may be correct to a certain degree, particularly as regards his fellow-Englishmen, who are notorious meat-eaters, and as to the facts that tissue-waste is comparatively slight and that the body framework rusts out rather than burns out. But in addition to the statements already made—that part of our nitrogenous food regulates the demand for oxygen, that part is doubtless a source of energy, and that still another part may be converted into fat—we should also remember that animal food is a concentrated food, that much energy has been expended in converting and storing it from the vegetable world, that it is stimulating and often appetizing, and that our digestive organs resemble more closely, at least as far as comparative weight is concerned, those of the carnivora rather than of the herbivora. These reasons, as well as the fact that animal proteids make up a considerable part of the only typically complete food which we have and which nature gives to the mammalian infant, would seem to indicate that we should be careful not to use too little nitrogenous food. On the other hand, the experiments of Chittenden and others tend to show that careful and thorough mastication automatically lessens the desire for and consumption of proteids, with a resultant increase in one's powers of endurance and free-

[1] McCollum: The Newer Knowledge of Nutrition, p. 148.

dom from fatigue. Moreover, these experiments and others indicate that it is probable that a considerable reduction in the protein quota of food would be of advantage to almost every one. Care must be taken, however, that this reduction shall not be too marked, for, according to McCollum, "there is no instance in our experience where a diet satisfactory in all other respects, but supplying just sufficient protein of good quality to support growth at approximately the maximum rate to the full adult size, has been found to promote as satisfactory nutrition over the whole span of adult life as would the same diet containing a more liberal supply of the protein factor."[1]

The proteid portion of our food is obtained from the albumin of meat and fish, from milk and eggs, and from the gluten of cereals and the vegetable casein (albumin) of the leguminous plants, such as peas, beans, etc. The proportion and properties of the albuminous matter vary, of course, in each of these, and even in the same substances under different circumstances; but all should be taken into consideration and used interchangeably if we wish to obtain the greatest variety and benefit in feeding, together with due economy of expense.

In this connection attention may again be directed to the notable fact that the leguminous plants, through the aid of certain species of bacteria, are able to absorb and store up in the form of proteids a considerable quantity of nitrogen from the surrounding atmosphere, and that these plants are, therefore, an important source of food-supply. But one of the discoveries of recent years is that proteins differ in quality as far as nutrition is concerned, and that the leguminous proteids are relatively low in value as compared with those from other sources.

Granting that most individuals probably eat more proteid and, therefore, animal food than is to their best advantage, the author still believes that any regimen of living based upon a strictly vegetarian diet will be likely

[1] The Newer Knowledge of Nutrition, 2d ed., p. 10.

to prove detrimental or not conducive to the highest welfare of any one who follows it. We must have a certain modicum of protein of good quality in our diet, and we now know that the proteins from vegetable sources are likely to be of low grade or quality as compared with those of animal origin.

As McCollum says,[1] "the vegetarian diet has been viewed from the wrong perspective. It is possible to make a fairly satisfactory diet of foods derived entirely from vegetable sources, but it is not easy to do so. It would be difficult for man to eat enough leafy foods to enable him to succeed with a strictly vegetarian diet. Such a diet will generally be of low protein content. The addition of small amounts of meat will be valuable when such a regimen is adhered to. Eggs, because of their relative richness in vitamins A and B, will be often more effective supplements and the same may be said of small amounts of glandular organs."

The carbohydrates that furnish food to the body and are one of the sources of the heat and energy upon which muscular motion and vital activity depend, are practically all derived, with the exception of milk-sugar, from the starches, sugars, and gums of the vegetable kingdom.

It has been shown that much the greater part of the digestion of carbohydrate food is due to the action of the pancreatic enzyme amylopsin; but we should not forget the action of the saliva, nor that thorough mastication greatly assists the subsequent digestion by breaking up the starch granules and exposing them more freely to the action of the digestive juices. The latter object is also obtained by crushing the cereals and by cooking the starch-containing foods, for "grinding and cooking lessen the labor of the jaws and salivary (and pancreatic) glands."

After the end-products (dextrose, levulose, etc.) of carbohydrate digestion have been absorbed from the

[1] The Newer Knowledge of Nutrition, 3d ed., p. 169.

alimentary canal, part of them, at least, are reconverted in the liver into animal starch or glycogen, and this portion becomes a part of the body-store of fuel. Fothergill says: "The liver stores up from each meal so much glycogen and gives it off as required; otherwise life would only be one dreary meal." Another and perhaps greater moiety of the digested carbohydrates is converted into fat and stored as adipose tissue in various parts of the body, as a further reserve of fuel for any emergency. "Many authorities state that fat is formed directly from carbohydrates, and the weight of evidence appears to favor this view; but whether it is so formed directly, or indirectly by retarding the metabolism of the fatty and proteid constituents of the food, there is no doubt that the consumption of carbohydrates results in the formation of fat within the body."[1] Moreover, "whatever the mixture of fats taken in as food, the fat of the body always has the same composition; this fact agrees with the conclusion that the metabolism and deposition of fat in the body are due to cell activity, and that the fat comes in part from the proteid and part from the carbohydrate foods."[2]

Another important function of the carbohydrate foods is the formation by their metabolism in the body of lactic and other acids, which are of the greatest value in nutrition and in maintaining the normal reactions of the body-fluids This is perhaps one of the chief reasons why fats and carbohydrates are not interconvertible in any prolonged dietary.

Fat is essentially a compound of glycerin with one or more fatty acids, usually stearic, palmitic, and oleic. The digestibility of a fat largely depends upon its being fluid at the body-temperature; therefore, as the melting-point of stearin is higher than this, the more of it that a fat contains, the less digestible and nutritious will the latter be. For this reason butter is more digestible than suet,

[1] Notter and Firth, Treatise on Hygiene, p. 254.
[2] Ibid., p. 253.

lard than mutton-fat, etc., and the more assimilable cod-liver oil is that from which the stearin has been removed.

Fat for food is derived from vegetable as well as animal sources, many seeds and nuts and some cereals, as oats and corn (maize), containing much fat. By improved methods it is becoming possible to supply fats in purer, cheaper, and more agreeable forms, so that they may now be freely used even by the poor, the very class that needs them most. "Butter fat and egg-yolk fat contain a growth-promoting ingredient (as does cod-liver oil) which appears to be more or less completely wanting in other dietary fats of both animal and vegetable origin."[1]

Under normal conditions it is probable that the body-fat or adipose tissue is almost never derived from the fat in food but rather, as stated, from the proteids and carbohydrates; but fat is also an essential part of tissue-structure, making up more than one-fifth of the solid matter of the brain and nerve tissues and one-sixth of muscle, and possibly serving as fuel when the cell-contents are oxidized. It is probable that this fat of active tissues comes, at least in part, from that ingested as food. It is also probable that the digested fats or their acids enter into combination with certain organic substances in the intestinal canal or in the lymph or blood, the resulting compounds being intermediate to ones still higher and essential in the structure of vital and active cells. Adami[2] has shown that in fatty degenerations and other pathological processes, as well as in many normal tissues, so-called "myelin globules" are to be found. These myelin globules prove to be compounds of cholesterin or of cholin or neurin with fatty acids. Moreover, lecithins, which are found in every cell and abundantly in the brain and nerves, as well as in blood corpuscles and lymph, in breaking up dissociate into

[1] Mendel, Journal of the American Medical Association, September 5, 1914, lxiii, No. 10, 822.

[2] The Myelins and Potential Fluid Crystalline Bodies of the Organism, Journal of the American Medical Association, February 9, 1907, pp. 463–469.

fatty acids, glycerophosphoric acid and cholin, or, according to Carbone, into fatty acids, neutral fats and cholesterin. Beyond the lecithins is protagon, "which is obtained especially from the brain and is a crystalline body containing lecithin and cerebrin." Thus it is seen how the derivatives from the fat in the diet become incorporated as component parts of the most complex tissues and organs. In any case, however, fat is a very important part of a man's diet, for not only is a small quantity necessary to the digestion of proteids, causing the formation in the body of larger amounts of fat than the quantity ingested and greatly improving the physical condition; but it may be and, when occasion requires, undoubtedly often is used directly as fuel without first being stored in the tissues.

As fat is a concentrated fuel-food, it is to be used freely when we want to keep the body warm or when we need extra force for any increased exertion. "On a diet rich in fat great muscular effort can be undergone with but little destruction of muscular tissue, and without increased urea discharge." The object of fat in the diet, then, may be said to be to give heat and energy as fuel, and, when necessary, to aid in the repair or building up of active tissue.

The constructive property of fat is especially valuable in the treatment of all wasting diseases, especially phthisis. Fothergill emphatically declares that "the great food for the strumous is fat," and also says: "Whenever there is any tendency to tubercle the individual should learn to eat fat, just as a seafaring man learns to swim. As a physician to a chest hospital, I have learned to dread the announcement that fat is no longer taken, especially if the individual is of strumous build, with a small, narrow chest. In my opinion, the existence of a considerable area of affected lung where the digestive powers keep up is less fraught with evil and less prognostically significant than intractable wasting with very little disease in the lung." In this connection, note that an excess of proteids in the diet causes a more rapid oxidation of fat, and

that an excess of fat or of carbohydrates lessens the absorption of oxygen and the oxidation of both fats and proteids. Also, that the free use of fluids is thought to favor an increase in the quantity of fat deposited in the body.

Fat is practically indigestible in the stomach, and some stomachs cannot tolerate it, especially when taken with other food; although usually a little fat assists in the digestion of proteids by stimulating the secretion of the gastric juice. Cases occur not rarely in which it is necessary that comparatively large quantities of fat should be ingested and yet in which there is apparently decided gastric intolerance of it. In such event success is often to be attained by giving the fat some little time after the regular meals, when the gastric digestion is approaching completion and the chyme is being passed out of the stomach to be further subjected to the action of the intestinal digestants. It may also be well to partially or wholly emulsify it, especially if there be faulty secretion of bile and pancreatic juice, and sometimes to disguise its taste with agreeable aromatics or flavors. In this way there is generally but little trouble in administering fats, even such as those which, like cod-liver oil, have a disagreeable taste and odor. Failing in this, we may still resort to inunctions, preferably of predigested or emulsified fats, and often with considerable advantage, since it has been experimentally shown that after passing through the skin fat may be taken up by the subcutaneous lymphatics and later be oxidized or metabolized almost as completely as if it had entered the system by way of the intestinal canal and thoracic duct.

Certain salts in definite proportions are necessary for the maintenance of health in the body. "Lime, chiefly in the form of phosphate, is absent from no tissue, and there is reason to think that no cell-growth can go on without it." Even the bacteria must have earthy phosphates for the purposes of growth. Chlorine, derived largely from the sodium chloride of food, is necessary to form the hydrochloric acid of the gastric juice, the chlorides also keeping in solution the globulins of the blood

and body-fluids and helping to dissolve the albumin. Phosphorus is necessary in the formation of the lecithin of nerve-tissues, as well as for the phosphates above mentioned, and those of potassium, magnesium, etc., which go to form bone. Potassium salts maintain the alkalinity of the solid tissues, and sodium salts that of the body-fluids. Iron is essential for the construction and nutrition of the blood-corpuscles, though small quantities of it are to be found in almost every other tissue.

But not only must the above inorganic salts be given in proper supply, but also certain ones of organic nature, in order to prevent conditions of malnutrition or disease. Those especially which are changed to form carbonates, as the lactates, tartrates, etc., or their respective acids, help to maintain the alkalinity of the system and appear to be most essential, as a scorbutic condition seems to be inevitably created or fostered by their absence. There is also some evidence that certain gouty conditions may be due to the removal of the natural vegetable salts by improper methods of cooking. The fact of the carbohydrates being an important source of these organic acids and salts has already been mentioned.

As a review of the preceding statements, the following quotation, from Notter and Firth,[1] may be of value:

"With regard to the necessity for all four classes of aliments, it can be affirmed with certainty that (putting scurvy out of the question) men can live for some time and can be healthy with a diet of proteids, fats, salts, and water. But special conditions of life, such as great exercise or exposure to very low temperature, appear to be necessary, and under usual conditions of life health is not very perfectly maintained on such a diet. It has not yet been shown that men can live in good health on proteids, carbohydrates, salts and water, without fat.

"The exact effect produced by the deprivation of any one of these classes is not yet known. An excess of the proteids causes a more rapid oxidation of fat, while an

[1] Treatise on Hygiene, p. 256.

excess of fat lessens the absorption of oxygen and hinders the metamorphosis of both fatty and albuminous tissues. The carbohydrates have the same effect when in excess, and appear to lessen the oxidation of the two other classes.

"It is generally admitted that the success of Banting's treatment of obesity is owing to two actions: the increased oxidizing effect on fat consequent on the increase of meat (especially if exercise be combined), and the lessened interference with the oxidation of fat consequent on the deprivation of starches.

"Health cannot be maintained on proteids, salts, and water alone; but, on the other hand, it cannot be maintained without them."

According to Winslow and Williamson:[1] "The average American diet is unnecessarily wasteful in its overemphasis on meat. The chief teachings of sound dietary hygiene may be summarized in the recommendation to eat less meat, to eat more vegetables and fruits, as sources of salts and vitamins, and, above all, to drink more milk as a source of complete proteins, salts and vitamines. The average consumption of milk in a community should be at least one pint per person per day, and the growing child should have one quart of milk a day. This estimate, of course, includes the milk used in the preparation of foods as well as that used for drinking."

They also present from *Food for Health's Sake*[2] "the following helpful list of the most important foods which supply each of the main essentials of the diet:

Energy.	Proteins.	Mineral salts.	Fats.
Fats	Milk	Milk	Milk
Oils	Meat	Eggs	Eggs
Grain products	Legumes	Vegetables	Vegetables
Milk	Nuts	Fruits	Fruits
	Whole-grain cereals	Whole-grain cereals	Whole-grain cereals
	Cheese		
	Fish		
	Eggs		

[1] Loc. cit., pp. 64–65.

[2] Miss Gillett: National Health Council Series.

From this "it will be noted that grain products and milk occur in all four columns, eggs in three columns, and vegetables and fruits in two columns, a fact which well illustrates their relative importance."

With many of our foods we require the addition of certain flavors, condiments, etc., which, though they have little or no real food-value in themselves in the sense of repairing tissue or furnishing energy, do much good, when not abused, by making the food more palatable, by stimulating the secretion of the digestive fluids, and by acting as carminatives. These condiments should not be omitted from the food of the sick or convalescent, for they have a value of their own, and are "agreeable to the palate and, in moderation, good for the digestive organs."

Reference has already been made to the recently discovered importance of the so-called vitamines.

"Through the 'vitamine' hypothesis, Funk attempted to account for the diseases beri-beri, scurvy, pellagra and rickets, as being each due to the lack of a specific chemical substance, a 'vitamine' in the diet. This was a very logical conclusion from the data available to Funk. There has since been secured much experimental evidence in support of the view that scurvy and pellagra do not arise from deficiency in the diet of specific chemical substances in the sense in which suggested, and this seems to be true also of rickets." On the other hand, McCollum and others seem to have demonstrated that while there is not a specific "vitamin" for each so-called "deficiency disease," the diet must contain, in addition to the long-recognized dietary factors, viz.: proteins, carbohydrates and fats, and a suitable supply of certain organic and inorganic salts, three and possibly four as yet unidentified substances or groups of substances. One of these is associated with certain fats, and is especially abundant in butter fat, egg yolk and the fats of the glandular organs such as the liver and kidney, but is not found in any fats or oils of vegetable origin. The second sub-

TABLE SHOWING COMPARATIVE VALUES AND COMPOSITION OF COMMON FOODSTUFFS.

Food.	Calories per pound.	Vitamines.			Percentage of			Ca.	Fe.	P.
		A	B	C	Fats.	Protein.	Carbo-hydrates.			
Lamb chops	1610	*	*	=	26.64	18 36		0 011	0 003	0.198
Roast beef	1400	*	*	*	26.54	17 46		0 010	0.003	0 188
Turkey	1320	*	*	–	22 85	21.05		0 012	0 003	0.227
Breast of lamb	1310	*	*	–	23 55	19 06	.	0 011	0 003	0.205
Sirloin steak	1100	*	*	*	18.46	18 86	.	0 011	0 003	0 203
Fresh ham	1040	*	*	–	14.17	24 75	...	0 014	0.004	0.267
Leg of lamb	1020	*	*	–	16.46	19.16	...	0.011	0.003	0.207
Salmon	890	*	*	–	12 77	21 96	. .	0.024	0.001	0.252
Leg of mutton	860	*	*	–	12 37	19.76	.	0.011	0.003	0.213
Round steak	685	*	*	*	22.85	21 06	..	0.012	0.003	0 229
Eggs	670	**	*	*	10.50	13 40		0 066	0.003	0 180
Halibut	550	*	*	–	5.19	18 56	.	0 020	0 001 –	0.213
Chicken	500	*	*	–	2 50	21 47	...	0.012	0 003	0.231
Oatmeal	1800	*	**	–	7.28	16 67	66.09	0.067	0.004	0 393
Farina	1640	*	**	–	1.40	10 98	76.14	0.022	0.001	0.126
Macaroni	1625	–	*	–	0.90	13 37	73.95	0 021	0 001	0.143
Corn-meal	1620	*	**	–	1.90	9 18	75.24	0.018	0.001	0 189
Barley	1615	*	**	–	1.05	8 48	77.64	0 020	0 002	0.181
Hominy	1610	*	**	–	0 60	8 28	78 83	0 007	0.001	0.096
Whole rice	1600	*	**	–	0.30	7 99	78.83	0.004	0 001	0.095
White bread	1180	–	*	–	1 60	9.08	53 19	0 029	0 001	0.091
Graham bread	1180	*	**	–	1.80	9 08	52 01	0 052	0 002	0 218
Corn bread	1175	*	**	–	4.69	7 88	46 20	0 015	0 001	0 162

Rye bread	1150	*	**	—	0.60	8.98	53.09	0.023	0.001	0.147
Whole wheat bread	1110	*	**	—	0.90	9.68	49.60	0.049	0.002 –	0.174
Condensed milk	1480	***	**	*	8.28	8.79	54.00	0.313	0.001	0.234
Cream	880	***	**	*	18.45	2.49	4.49	0.097	0.001 –	0.085
Whole milk	320	***	**	*	3.99	3.29	4.99	0.120	0.001 –	0.093
Buttermilk	160	*	**	*	0.50	2.99	4.80	0.105	0.001 –	0.096
Baked beans	600	—	**	—	2.49	6.89	19.56	0.062	0.003	0.181
Lima beans	555	*	**	*	0.70	7.09	21.95	0.025	0.002	0.118
Green corn	455	*	**	—	1.20	2.79	18.96	0.006	0.001 –	0.102
Potatoes	380	*	**	*	0.10	2.18	18.36	0.013	0.001	0.057
Parsnips	295	—	**	—	0.50	1.61	13.47	0.059	0.001 –	0.076
Peas	250	**	**	*	0.20	4.25	9.78	0.014	0.001	0.066
Onions	220	—	**	**	0.30	1.60	9.86	0.033	0.001 –	0.045
Carrots	205	**	*	*	0.40	1.10	9.28	0.056	0.001 –	0.045
String beans	185	**	**	*	0.30	2.29	7.39	0.045	0.001	0.051
Beets	180	—	*	—	0.10	1.60	9.68	0.025	0.001 –	0.033
Turnips	180	—	**	—	0.20	1.30	8.08	0.063	0.001 –	0.046
Cabbage	145	*	**	*	0.30	1.56	5.59	0.045	0.001	0.029
Cauliflower	140	*	**	*	0.50	1.80	4.69	0.123	0.001 –	0.061
Spinach	110	***	**	—	0.30	2.10	3.19	0.067	0.004	0.068
Squash	105	**	—	—	0.20	0.70	4.49	0.009	0.001 –	0.008
Raisins	1560	*	*	—	3.29	2.59	75.94	0.065	0.005	0.131
Prunes	1370	—	*	—	...	2.10	73.15	0.054	0.003	0.105
Pineapple	690	**	**	—	0.70	0.40	36.32	0.063	0.002	0.098
Apples	285	*	*	*	0.50	0.40	14.21	0.008	0.001 –	0.013
Oranges	235	*	**	***	...	...	10.78	0.045	0.001 –	0.021
Peaches	215	—	*	*	0.10	0.70	10.78	0.018	0.001 –	0.027
Lemon-juice	180	—	**	***	...	...	9.78	0.024		
Tomatoes	105	**	***	***	0.40	0.90	3.89	0.011	0.001 –	0.026

stance or group of substances of chemically unidentified nature is never associated with fats or oils of either animal or vegetable origin. It is widely distributed in natural foods, and can be isolated in a concentrated, but not a pure form, from natural foodstuffs by extraction of the latter with either water or alcohol. This aqueous or alcoholic extract always contains the substance which prevents and cures polyneuritis (otherwise known as beri-beri).

For these two substances or groups of substances, as yet chemically unidentified, McCollum and Kennedy have proposed the terms "fat-soluble A" and "water-soluble "B." The former of these, which is also to be found in the *leaves* of plants and is fairly abundant in the *germs* of seeds, but not in the stored up food reserve of seeds, roots, tubers, nor in animal flesh (muscle), seems to be absolutely essential for growth and the maintenance of health in the body. It also prevents the development of a disease of the eyes known as xerophthalmia, while the second substance, the "fat-soluble B." prevents, as stated, the development of beri-beri. It would thus seem that the two maladies just mentioned are, "deficiency diseases" due to the lack of a specific substance or "vitamine" in the diet. On the other hand, while faulty diet is undoubtedly a factor in the causation of such diseases as scurvy, rickets and pellagra, additional factors, such as the presence of infective organisms, lack of certain proteins or salts, etc., may help to account for the development of one or the other of these maladies. Moreover, it seems to be fairly well established that there is a vitamine C, to be found in various fruit juices and certain fresh vegetables, that is a preventive of scurvy; while McCollum and others apparently have demonstrated that there is also a vitamine D to be found in butter fat, cod-liver and other fish oils and even in coconut oil that aids in the deposition of calcium and in the prevention and cure of rickets.

It will be impossible to go into details concerning all

the articles commonly used as foods, but there are certain facts that should be well known and which cannot properly be omitted from a work of this kind.

MILK.

Milk is a typical foodstuff, complete in itself, in that it contains all the food-principles and these in nearly the proper proportion, at least for infant life. The casein and albumin represent the proteids; the cream, the fats; and the lactose or milk-sugar is a concentrated carbohydrate—all being in combination with sufficient salts and water.

Milk should constitute almost the sole food of infants during the earlier months of life; and that it is capable of sustaining adult life almost indefinitely, especially where there is little demand for heat or the expenditure of force, has been shown in numerous instances.[1] Coplin and Bevan mention the case of a patient who lived and thrived on milk alone for over thirteen months, and of another who lived for three years on the same diet. But the limited proportion of carbohydrates, even though concentrated, is not all-sufficient for the maintenance of great vital activity, and for persons in ordinary life some addition to the diet is necessary.

The albumin of milk is coagulated by heat, but the casein, which constitutes the greater part of the proteid element, is clotted by an acid or by an enzyme such as rennin; and as both acid and rennin are present in normal gastric juice, it would seem that the preliminary coagulation of casein was essential to its proper digestion. It should be remembered, however, that the casein of cows' milk forms a much harder and firmer clot than does that of human milk, and that the former should, therefore, never be hastily introduced into the stomach in large

[1] It is understood, of course, that in order to be a proper food for young infants, cows' milk must be modified so as to resemble human milk as nearly as possible, and so as to give the proportion of the respective food-principles which each particular case may need.

volumes, but should rather be taken slowly and preferably with other food which will help to disintegrate the curd. In the feeding of children, an alkali, such as lime-water, when mixed with the milk, is thought to soften the curd and possibly to facilitate digestion.

Outside of the body, fermentative changes due to certain bacteria may convert the milk-sugar into lactic acid, which coagulates the casein and "sours" the milk. Another peculiarity of casein is the tenacity with which it holds large quantities of phosphate of lime, one of the most valuable of food-salts.

Sometimes it is advantageous or necessary to predigest milk for infants or sick persons, but if the digestion be carried beyond a certain point, the consequent peptones and albumoses will give the milk a bitter and disagreeable taste. In the feeding of infants it must not be forgotten that the percentage composition of human milk is different from that of cows' milk, and that the latter will need dilution to decrease the proteid proportion, and also an increase of fat and carbohydrates. As a child grows older and more active, it becomes necessary to add to the milk additional carbohydrates, which should be easy of digestion and soluble, milk-sugar and predigested starches in the form of maltose and its allies being preferable.

Milk should always be kept as cool as possible and in closed vessels, not only to prevent it from absorbing disagreeable odors and harmful gases, which it is very prone to do, but to exclude dirt and bacteria as well. As it is an excellent culture-medium, and as it is commonly liable to be exposed to contamination by organisms from many sources before it reaches the consumer, fermentative or other harmful chemical changes are almost certain to occur in it if the temperature conditions are at all favorable. For this reason it is necessary that the greatest care should be used in the handling of the milk from the time it leaves the cow until it is used, and, for the feeding of children and whenever there is any possibility of it

being the carrier of disease germs of any kind, it should be properly pasteurized or sterilized and then kept free from further contamination until used. In fact, pasteurized milk, modified to resemble the human secretion, will usually be superior to any other artificial food for infants, but the operation should always be done before fermentation has begun and harmful products have been developed in the milk. Sterilization may slightly alter the taste and other properties of the milk by coagulating the albumin, but it is doubtful whether it makes any real change in its digestibility.

Pasteurization.—"By pasteurization is meant raising the temperature of the milk to such an extent and for a sufficiently long period as to ensure the destruction of the lactic acid bacteria and pathogenic organisms without affecting the enzymes or the lactalbumin."[1] Accordingly, for a general standard the minimum temperature and duration of time for successful pasteurization may be respectively placed at 60° C. (140° F.) and twenty minutes, although temperatures much higher and varying exposures, both shorter and longer, are employed, depending upon the kind of apparatus or method used.

Milk that has been pasteurized is not *entirely* sterile; consequently it should be cooled quickly and be kept at a low temperature until used. Otherwise the saprophytic bacteria surviving the process may multiply rapidly, especially as they are now deprived of the destroying or retarding influence of the lactic acid bacteria, and may even produce harmful decomposition products in the milk, which remains sweet and apparently free from harm. For the same reason, it is a better culture medium even than raw milk for whatever new organisms gain access to it, whereas the laity are apt to think that the pasteurizing process has rendered it safe for an indefinite time and, therefore, to be more careless regarding its protection than if it were delivered to them in its natural state.

[1] Harrington, 5th ed., p. 119.

For these reasons and because there seems to be some evidence that pasteurized milk may not be as wholesome, especially for young children, as the natural fluid, the writer feels that the pasteurization of a public milk supply is only to be advocated or approved when it is manifestly impossible or impracticable, as in a large city, to secure the observance of all of the sanitary procedures whereby it may be transmitted in a safe and wholesome condition from cow and dairy to the actual consumer. On the other hand, home pasteurization may be most advisable, particularly if there is any suspicion of infection, as in time of epidemics, or where opportunity for home refrigeration and proper care are lacking.

The cream of milk is fat in its most digestible and acceptable form, and should not be removed from milk if the latter is to be used as food. If the milk seems to be too rich, it may be advisable to skim it, giving it in some form or other with the regular meal, and reserving the cream until a couple of hours or so later, when gastric digestion is approaching completion. One may also often avoid the use of cod-liver oil and similar fats by taking cream—either plain or whipped and flavored—in this way *i. e.*, some little time after the meals. It should not be forgotten that, according to Mendel, McCollum and others, the fat of cream and eggs contains an important growth promoting ingredient, which is much less abundant or entirely lacking in other commonly used fats.

"Milk is just as necessary in the diet of the adult as in that of the growing child. Any diet which will not support normal development in the young will not support optimum well-being in the adult. Milk is our greatest protective food, and its use must be increased. The price must be allowed to go up, so long as the cost of production makes it necessary, and up as far as is essential to make milk production a profitable business. Unless this is done, the effects will soon become apparent in a lowering of our standards of health and efficiency."[1]

[1] McCollum: The Newer Knowledge of Nutrition, p. 153.

Skimmed milk and buttermilk may be used freely as beverages, as both are refreshing and healthful with some little food-value; buttermilk is also acceptable to many persons on account of its lactic acid. "Koumiss" and "kefir" are both prepared from milk through the action of certain fermentative organisms, which also bring about a partial digestion of the casein. Each contains carbonic and lactic acids, though in different proportions, some peptones or albumoses, and a very little alcohol. They are wholesome, agreeable to most palates, and are usually retained and utilized by stomachs rebellious to almost all other foods. Furthermore, Metchnikoff[1] strongly advocates their use, since lactic acid and the microörganisms that cause its formation are antagonistic to the microbes of putrefaction, which multiply only in alkaline substances. The beverages mentioned, therefore, tend to prevent the development in the intestinal canal of such putrefactive germs and of ptomaïns and other poisonous products of decomposition which, when absorbed into the circulation, give rise to the manifold symptoms of auto-intoxication.

Milk may be a factor in the causation of disease in a number of ways. Large and tough curds of cows' milk in the stomach often cause mechanical irritation and indigestion, especially in young children, and the products of the fermentative action already referred to are a frequent source of serious intestinal disorders; while if further decomposition occurs, a very poisonous ptomaïn, called tyrotoxicon, may be developed and may cause even fatal results to those using the milk. This same substance is also liable to occur in any milk-product, such as cheese or ice-cream, and is usually the cause or agent in the cases of poisoning by such products that are so frequently reported.

Again, the active principles of plants which the cow has eaten may be transmitted by the milk and produce their physiological effects. But a graver question is

[1] The Nature of Man, Chapter X.

whether disease may be transmitted directly from the animals to man by this almost universal foodstuff. Every one knows that the milk from sick cows may cause marked disturbance of health, and there is fair evidence that cattle are subject to certain diseases identical with or very similar to human maladies, the milk serving as a carrier for the contagium.

Though some authorities still question whether tuberculosis can be thus transmitted unless the milk-glands themselves are affected, the great prevalence of the disease among cattle and experimental evidence both make it certain that milk is often the means of transmitting the infection, and many believe that by far the larger number of the many cases of infantile tuberculosis have origin from this source. The condemnation and destruction of all cattle that show symptoms of tubercular infection is certainly one of the most important and effective methods of checking the spread of and eliminating this very prevalent and deadly malady. The use of inoculations of tuberculin as a means of diagnosis has materially contributed to this end, for by its aid the presence of the disease is often indicated in many animals that have as yet evinced no physical signs of the disease.

A British Royal Commission[1] have found "that milk containing bovine tubercle bacilli can, by feeding, produce tuberculosis in apes, and they have no doubt that many cases of human tuberculosis, especially in children, are due to this germ. The same conclusions had been reached by the United States Agricultural Department's investigators. The importance of proper bacteriologic analyses of milk and the inspection of dairies cannot be sufficiently emphasized, and it is quite possible that while the milk of tuberculous cows may be comparatively innocuous to adults of fair resisting powers, it may be extremely dangerous to young children and those having a predisposition to tuberculous infection."

[1] Journal of the American Medical Association, Feb. 9, 1907, p. 528

Milk, like other foodstuffs, may also become a disease-carrier through infection from dust and disease germs, especially in the vicinity of places where infectious matter is allowed to dry, become pulverized, and to be taken up into the atmosphere by winds and air-currents. But a more common danger is through carelessness in handling by infected persons or by the admixture with it of water containing disease germs. Epidemics of diphtheria, scarlet fever, typhoid fever, and cholera have all been traced to contaminated milk-supplies, and it is a question whether many of the more or less local outbreaks in cities are not of this character. The writer is personally cognizant of five cases of undoubted scarlet fever that occurred almost simultaneously in one locality and in which, apparently, the only common source was the milk-supply. He was unable to discover that there had been any illness either among the cattle or in the family of the milkman in question, but he has always felt that there was considerable evasion in replying to the inquiries made. He also has knowledge of a localized epidemic of typhoid fever due to the infection of a common milk-supply. In this instance the dissemination of the disease was traced to the use of a rubber tube for siphoning the milk from a receiving can to the distributing jars, the dairyman and his assistants exhausting the air from the same by suction by the mouth. At the time this was discovered the dairyman and at least one of his men were ill with typhoid fever in a hospital.

Newman states that since 1857 more than one hundred and sixty epidemics of typhoid fever have been traced to a polluted milk-supply, and quotes Schuder as saying "that 17 per cent. of all typhoid epidemics are due to the consumption of infected milk." Moreover, Newman counts up "some thirty outbreaks of milk-borne diphtheria" and some seventy of scarlet fever, and also says that "there are three (other) very common diseases in which milk has been proved to play a not inconsiderable

part, viz., thrush, sore throat, and diarrhea." He gives the following characteristics of milk-borne epidemics:[1]

(*a*) There is a special incidence of the disease upon the track of the implicated milk-supply. It is localized to such areas.

(*b*) Better-class houses and persons generally suffer most.

(*c*) Milk drinkers are chiefly affected, and those suffer most who are large consumers of raw milk.

(*d*) Women and children suffer most, and frequently adults suffer proportionately more than children.

(*e*) Incubation periods are shortened.

(*f*) There is a sudden onset and a rapid decline.

(*g*) Multiple cases in one house occur simultaneously.

(*h*) Clinically, the attacks of disease are often mild, contact infectivity is reduced, and the mortality rate is lower than usual.

Experience is also rapidly accumulating that infecting germs are implanted upon or in many foods by house-flies, roaches, and other insects, as well as by larger vermin, and even domestic animals, such as dogs and cats. Typhoid bacilli having been obtained from the bodies of flies from a house where eight cases of typhoid fever had occurred, further experiments showed that flies fed with these germs are able to convey them to other objects for as long as twenty-three days afterward. The bacilli have also been found on the heads, legs, and wings of flies five days after, and in their intestines nine days after such feeding.[2] Consequently, every effort should be made to protect food-supplies of all kinds and especially milk from such contamination by insects and vermin, especially in time of epidemics, for we should realize that though most of the cases of an epidemic may arise from a common source, such as a polluted water-supply or a so-called "carrier," there will possibly be numerous sporadic cases in which the infection has been transmitted as above.

The possibility of milk as a source of danger to health

[1] Bacteriology and the Public Health, 3d edition, p. 218.

[2] Ficker, Archives of Hygiene, 1903, xlvi, 274.

having been shown, the lessons to be had are these: that not only must there be the greatest care in the handling and keeping of milk until it is consumed, but there must also be frequent and careful inspection of the animals from which it comes and of their environment; that no milk from any diseased cow should ever be used as food; that all who handle it in any way shall be in good health and free from the possibility of infecting it; that wherever there is the suspicion or possibility of the milk being contaminated with disease germs, it must be thoroughly pasteurized, and that any change from its normal condition should also forbid its use.

Fortunately, good milk can almost always be had so cheaply and readily that no serious hardship inures by the strict observance of these rules, and the public should be educated to demand as well as to pay fairly for pure milk from healthy animals, these matters being even more important than that the quality, as shown by analysis, should always be up to a certain standard.

Good milk in bulk should be opaque, of clear ivory-white color, should have no peculiar smell or taste nor leave any deposit on standing. Nor should it show any change in taste or appearance upon boiling, excepting the formation of the slight skin of coagulated albumin due to the heating. Details regarding the composition of milk and the methods for its examination will be found in the final chapter of this volume.

The addition of preservatives to milk is very common, and should be discountenanced, not only because they are usually added in quantities harmful or prejudicial to health, but also, and almost more important, because milk should be supplied to consumers in such a condition and state as not to need the preservative, the presence of the latter being therefore suspicious. The same reasons also justify the condemnation of the use of artificial coloring-matters. The chemicals commonly used as preservatives are boric acid, salicylic acid, and formalde-

hyde. Of these, the salicylic acid is probably most harmful, as the habitual ingestion of even a moderate quantity is apt to be deleterious to the kidneys. (See Chapter XVII.)

Cheese is a most valuable foodstuff, and, as a milk-product, may be considered at this time. Good cheese usually contains twice as much nitrogen and three times as much fat as the same weight of meat, but many persons apparently find it difficult of digestion and can eat but little of it. This is perhaps because the nutriment is so concentrated and because, as usually eaten, it forms in the stomach a tough or pasty solid lump into which the gastric secretion cannot penetrate. Mattieu Williams has remarked that we habitually use cheese in the conditions in which it is most indigestible—either in its raw state or cooked into a leathery mass—and he asserts that if the cooking is such that it is thoroughly mixed with other articles of food, or if it be masticated with other food, so that this commingling of particles takes place, it will be found to be quite digestible by almost every one. He also advises the addition of a small amount of potassium carbonate in the cooking, as this favors solution of the casein and replaces that salt which is removed in the whey. As a food, only cheese made from whole milk, or from that to which extra cream has been added, satisfies all requirements, and skim-milk cheeses are decidedly less nutritious than those having the full proportion of fat.

Butter, consisting as it does largely of the fat of milk, is a highly nutritious article of food and one of the most digestible of its class. It should be pure, sweet, and free from rancidity, and while some of the substitutes offered in its stead are entirely wholesome, they should never be sold as butter or used to adulterate it. Neither should butter contain an excess of water nor of casein, as its food-value, weight for weight, is thereby accordingly lessened.

EGGS.

Eggs yield almost their full weight of food in a concentrated and very digestible condition, and are valuable on this account, as well as for their palatability and their value in the preparation of many dishes. Although containing practically no carbohydrates, they have sufficient food-material in themselves for the complete development of the living chick with the aid of nothing external except the oxygen which passes through the shell: the lack of the carbohydrate element, ordinarily one of the essential food-principles, is supplied by the heat from the mother hen or incubator which is sufficient for the development and maintenance of the vital processes, since the unhatched creature wastes almost no energy in physical activity.

The white of egg is almost pure albumin with a little water and some salts; the yolk contains about 30 per cent. of fat and some albumin. The albumin coagulates at about 170° F., but if it is exposed to a still higher temperature for any but a very short period of time, it becomes hard and difficult of digestion. A so-called "soft-boiled" egg is scarcely more difficult of digestion than an uncooked one, and is certainly more palatable to almost every one.

Eggs, milk, and cheese may be made into many nutritious and palatable combinations which furnish food especially agreeable to the sick, as well as to those whose appetite and digestive functions have not been impaired.

MEAT.

Good meat, when deprived of its contained water, is a concentrated food, and is used not only on account of the large amount of nutriment it contains, but also for its rich and agreeable flavor. It represents much vegetable matter converted into its present palatable and more digestible form by the metabolic activity of the

animals from which it came. It contains all the essential food-principles, the carbohydrates, however, being present as muscle-sugar or inosite and, as in milk, in very small proportion. In all fresh meat there is much water, but more in lean than in fat meat; fat bacon contains 60 per cent.; lean beef, from 75 to 78 per cent. of water. As the proportion of fat increases, the quantity of albuminoids or proteids decreases: thus, lean beef may have only 2 per cent. of fat to from 20 to 24 per cent. of proteids, while bacon has about 24 per cent. of fat to 15 per cent. of proteids.

Of the varieties of meat commonly used, beef is the most nutritious. Good beef should not be too pale nor too dark, should show no blood-clots, have almost no odor, be elastic and not soggy to the touch, be well marbled with clean, white fat, and have compact flesh. Dark beef indicates that the animal was not properly bled, or has had some febrile disease; wet and flabby meat, that it is approaching decomposition. The flesh of young animals is more tender than that of older ones, but not so digestible, partly because the young flesh cannot be so thoroughly masticated and the fibres so well separated. Therefore, veal is not as digestible as beef, nor lamb as mutton. "Young flesh is less stimulating and nutritious and more gelatinous than that of the adult." (Vaughan.) Veal should not be too pale, as that indicates antemortem bleeding or too young an animal. The calf should be at least one month old before the killing.

Mutton is more digestible than beef, but not so nutritious. Its flavor is objectionable to some. Pork is an economical food for the poor man, as pigs of good stock store up three times as much of the food they eat as does the ox. The flesh is also easily preserved by drying or smoking, and ham and bacon are exceptions to the rule that dried meats are more indigestible than fresh ones. Again, pork fat furnishes much heat for cold weather by its oxidation and combustion in the body. But it must be remembered that it requires good digestive power to dis-

pose of it, and that much pork is not to be advised for those of sedentary habits; also that certain parasites are especially liable to infest the tissues of the pig and to be transmitted thence to man.

The flesh of poultry is acceptable to most palates, if not too old and tough. White meat is more digestible than the dark, but not so nutritious or rich in flavor, since the latter is more highly nitrogenous. Chicken broth is more nutritious and more laxative than that made from mutton.

Fish is not sufficiently stimulating to constitute the chief flesh diet of a people, but it furnishes variety, and on account of its contained phosphorus should be used largely by those subject to neurosal affections. White-meated fish are more delicate in flavor and more easily digested, but not so stimulating as those of red flesh. Some fish are poisonous, either by nature or from inhabiting foul waters; while any fish may become so if undergoing decomposition. Shell-fish are particularly liable to develop poisonous ptomaïns in the process of decomposition, and, consequently, only such as are absolutely fresh should be used.

Oysters and clams which have been taken from a water contaminated by sewage may also convey the germs of infectious diseases, such as typhoid fever; instances of this having been demonstrated in the investigation of an epidemic of the latter disease in Connecticut, which was reported by Professor Conn, of Wesleyan University, in a similar epidemic at Atlantic City, N. J., in 1903, and still more recently (in 1925) in a simultaneous typhoid outbreak in New York City, Chicago and Washington, D. C., the infected oysters having been taken from polluted waters in the vicinity of New York and shipped by a single dealer to the cities mentioned.[1]

"The following meats should not be eaten: (1) The flesh of all animals dead of internal diseases, or which have been killed while suffering from such diseases, or

[1] Journal American Medical Association lxxxiv, p. 596. See also lxxxiv, p. 641, and lxxxv, pp. 218 and 911.

animals killed by overdriving. (2) The flesh of animals with contagious diseases that may be transmitted to man. (3) The flesh of animals that have been poisoned. (4) The flesh of animals with severe infectious diseases, as pyemia, etc. (5) Flesh that contains parasites that may be transmitted to man. (6) All putrid flesh."[1]

Competent inspectors are appointed by governmental and state authorities to examine the various meats offered for sale in large cities, and undoubtedly do much good in preventing the sale of meat that is unfit for use. Unfortunately, from false ideas of economy in many communities, the authorized inspectors have been too few in number to be able to attend to all the work that should be done by them.

Coplin and Bevan give the following as diseases which are to be specially guarded against: In cattle, epidemic pleuropneumonia, foot-and-mouth disease, contagious typhus, anthrax, tuberculosis, actinomycosis, Texas fever, dropsical affections, and indigestion. In sheep, braxy, variola ovina, black quarter, phthisis, fluke disease, and gid. In swine, anthrax, hog cholera, measles, and trichiniasis.[2] It should also be remembered that the intestinal parasites, such as tape-worms and round-worms, often, if not usually, gain entrance into the system through the ingestion of meat containing them in their embryonal or larval stages.

Therefore, in cooking meat, every part should be heated to at least 160° F. sufficiently long to destroy any disease germs or parasites it may contain, as very rare meat may still harbor these organisms in a living state. Tuberculosis, for instance, may be incurred by eating flesh imperfectly cooked, since its germs are quite resistant; though it must be said that this disease is not so likely to affect the muscular tissues of an animal as are others of the maladies mentioned. The development of ptomaïns in flesh may also make it quite poisonous, and this is especially likely

[1] Gerlach.

[2] Manual of Practical Hygiene, 1st edition, p. 132 et seq.

to take place in meats that have been kept for a long time after killing or in those preserved in cans or other packages that have been imperfectly heated or sealed.

Meat is also cooked to improve it in appearance and to make it more agreeable to the palate and to aid digestion. As already stated, the effect of cooking upon muscle-tissue is "to loosen the bundles of fibrillæ from each other so that they are readily torn asunder or crushed by the teeth." Perfectly cooked flesh is more savory than that which is either underdone or overdone. Meat cooked before *rigor mortis* sets in may be tender; cooked during the rigor, it is tough and is masticated with difficulty; after the rigor it is more likely to be tender when cooked than at any previous time.

In cooking meat, the ultimate condition in which we wish it to be should always be kept in mind, and pains should also be taken not to overcook or use too high a temperature. The processes pursued in making a palatable soup or broth, and in cooking meat so that it may retain all its juices, salts, and flavors, are radically different. In the first case, it is desired to extract as much of the soluble constituents of the flesh as possible, and to do this the meat should be cut into small pieces and allowed to remain for a time in cold water, this afterward being very gradually raised to a temperature of about 160° F. In this way the juices exude and the salts and soluble parts of the meat are dissolved before the pores are closed by the coagulation of the albumin. On the other hand, if it is desired to retain the juices and savor in the meat, the piece should be as large as possible that the surface exposed will be small in proportion to the volume. The meat is to be first subjected to a temperature as high as possible that the surface may be cooked at once and the albumin coagulated, the juices being thus prevented from escaping by the sealing of the pores. In boiling, this end is attained by plunging the meat at once into boiling water; in roasting, by having the fire or oven very hot. After this first heating it is best to lessen the degree

of heat somewhat, that the subsequent cooking of the interior may go on more slowly and the temperature within may not rise above the coagulating-point and make the fibres hard and stringy. Meat cooked in this way should be tender, juicy, and rich in flavor. Broiling or grilling is, of course, but a modified roasting.

Soups and broths made of meat-juices alone and without the addition of other substances are stimulating rather than nutritious, as they contain little albumin, carbohydrates, or fat. However, if certain vegetables be added to the soup, the latter will gain sufficient of these food-principles and be highly nutritious and such vegetable soups are of great value in all schemes of economic cooking. Bones are also of value on account of the salts, gelatin, and other soluble organic matter which they contain, and used with vegetables they make especially nutritious and easily digested soups.

The meat from which soup has been made, on the other hand, is not all that is desirable, for though it still contains albumin and fat, it has lost its salts and savoriness and is unpalatable, and therefore not easily digested. It needs something—a sauce or condiment, or preferably a meat-extract, for meat-extracts are nothing but thin soups evaporated to dryness or condensed. Or, if both soup and the meat be taken at the same meal, the things lacking in each are supplied by the other, and the needs of digestion and nutrition are supplied.

Frying meat, as it is commonly practised, should not be tolerated, as it renders the albumin of the flesh extremely tough, besides soaking it with fat or grease and thus greatly increasing the difficulty of its digestion. But frying by total immersion in boiling fat is an excellent way of cooking meats containing much water, and especially fish, for the boiling-point of fat or oil is very high and the meat is instantly cooked on the outside, while the water in the interior, being converted into steam, prevents the ingress of fat by its expansion, cooks the albumin, and leaves the flesh in a light, flaky condi-

tion. But the fat must be boiling hot when the meat is immersed, and the latter should not be allowed to remain in the former longer than just suffices for perfect cooking.

Beef-tea as ordinarily made is only a thin extract of beef, the stimulating properties of which will be considered hereafter. To make a beef-tea containing any considerable amount of nutriment, the meat from which the juices have been extracted should be dried, pounded fine, and all fibrous and tendinous portions removed. This pounded beef should then be added to the liquid extract, as then only is it really a food. Moreover, the mixture should always be seasoned, even for the sick, that it may be thoroughly acceptable to both palate and stomach. In making the extract, it should be remembered that the meat should be cut into very small pieces and added to cold water in about the proportion of one pound of lean meat to one pint of water, and that the whole should be brought to the boiling-point very slowly.

CEREALS.

The cereals form one of the most valuable kinds of food. All but rice contain considerable proteid matter—from 10 to 20 per cent.—beside carbohydrates, which predominate, some fat, and a goodly proportion of phosphates. Rice has only 5 per cent. of proteids to 75 per cent. of starch, but it is easily digested, and is therefore a valuable food for the young and the sick; it is also well fitted as a chief food for dwellers in hot climates on account of its low heat-production.

Wheat is the most nutritious cereal, and bread made from it is aptly called "the staff of life," since it is a food which, with the addition of a little extra fat and albumin, furnishes the essentials in proper proportion for the support of life. Barley closely resembles wheat in composition, and rye also is rich in nutriment, though perhaps a little more difficult of digestion than wheat. Oats are valuable on account of the large amount of fat

they contain—over 5 per cent.—beside a full share of proteids, starch, and salts. But ordinary oatmeal needs vigorous digestive functions, and where the latter are lacking it is often productive of intestinal disturbance and irritation. Corn or maize, though not a true cereal, furnishes a valuable food with considerable fat; it also contains a vegetable fibrin. The proteid constituents of the cereals are vegetable albumin, casein, and gluten, the last of these being most abundant in wheat and perhaps of the highest food-value.

Grinding breaks up the grain and the starch granules of the cereals, aids in separating indigestible parts, and renders the starch much more suitable for cooking. Wheat flour ground by the old method should be soft and smooth, but that made by the new roller-process is more apt to be slightly granular. It should not be too white, as that indicates a lack of the proper proportion of gluten, and should contain everything but the outer husk of the grain. The inner coats should be retained in the flour, as they hold a considerable part of the gluten and practically all of the grain salts and possibly the vitamines.[1] Corn-meal should be dry and powdery, or at least not too granular. Flour of any kind should be kept well covered in a dry place, and should contain no living organisms nor any adulterants.

Bread is practically made of flour, water, and salt, though sugar, milk, etc., may be added to improve the flavor. As flour and water alone make a tough and indigestible mass, bread is leavened to make it easier of mastication and digestion, and for this purpose either yeast, baking-powder, or aëration is employed. Yeast at the proper temperature rapidly converts some of the starch or sugar into carbon dioxide and alcohol, the former of which in escaping makes the dough porous and light, the walls of the cavities it produces being kept from collaps-

[1] The influence of polished rice as a factor in the causation of the disease beri-beri has been shown to be due to the loss of the vitamines in the germ and outer coating of the rice grains.

ing by the tenacity of the gluten until the heat fixes them permanently. As the heat of baking dissipates both the gas and alcohol, from 10 to 12 per cent. of the weight of the flour used is lost by this method. Moreover, if the fermentation goes beyond a certain point, lactic and acetic acids are formed and the bread becomes "sour." Consequently, it has been advised that the yeast method be discarded, and that the leavening be done by means of baking-powders or aëration. Carbon dioxide is evolved from the baking-powders upon the application of heat and moisture, and the bread is made light by the gas, with no loss of food-substance, and, if the powders are pure, with nothing harmful added to the bread. There should be no alum or other adulterants in baking-powders nor in the flour itself. Alum unites with the phosphates of the flour, rendering them insoluble and preventing their absorption from the alimentary tract. Bread may also be leavened on a large scale by forcing air or carbon dioxide under high pressure into the dough, or by mixing the flour with cold water heavily charged with the latter gas. In this method, also, there can be no loss of food-material nor any detriment to the bread, provided cleanly precautions are observed.

Good wheat bread should be almost white, light, sweet, spongy, and with a crust easily broken and equal in bulk to about one-quarter of the loaf. As considerable of the starch has been converted into dextrine in the crust, the latter is more easily digested than the interior of the loaf. Fresh bread is not nearly so digestible as that which is a day or two old. As stated, bread needs only a little added fat and albumin to make it a perfect food, the former of which, at least, is almost if not quite sufficiently supplied in the butter which is commonly used upon it.

VEGETABLES.

The vegetables in common use are valuable articles of food in that they give us the larger portion of carbohy-

drates and also furnish an agreeable variety from day to day. In the fresh state they contain considerable water—from 75 to 90 or 95 per cent.—the residue being mainly one or another of the carbohydrates. Potatoes exemplify this well, since they contain but little proteids and fat, and practically all of their solid matter is starch. On account of their customary cheapness and ease of growth and storage they are usually considered to be a valuable article of food for the poor man, but it should not be forgotten that other foods which are apparently more expensive may at times be actually cheaper than potatoes, both on account of containing those principles which the latter lack and because they require less expenditure of digestive energy. (See chart, page 324.) Beets contain much sugar and are nutritious, palatable, and easily digested. Onions have considerable sulphur, and should be used freely when its need is indicated. Cabbage, cress, chard, lettuce and other greens are especially valuable for the organic salts and vitamins which they contain, and because they serve so well as relishes. Spinach is said to contain more assimilable iron than any other article of food commonly used. Celery and lettuce are nerve sedatives, and asparagus acts as a diuretic and is thought to be of special benefit to the kidneys.

A caution should be introduced here concerning the use of raw vegetables which may carry from the soil the germs of certain infectious diseases derived from the fertilizers used in the field or from other sources. There can be no doubt that these have been the cause of infection in certain cases, as of typhoid fever, and Metchnikoff has pointed out that while such germs are probably destroyed by the normal bacteria and reactions of the digestive tract, an abnormal condition of the latter may permit their introduction and the development of their specific maladies.

The seeds of the leguminous group of plants, such as peas, beans, lentils, etc., contain from 22 to 25 per cent. of proteid matter in the form of vegetable casein, and

almost 50 per cent. of starch. It is on account of this abundance of food-matter that they make such a valuable addition to soups and the like, and for the same reason they should also be used in any dietary where economy of expense is a factor. Green peas and beans are much more digestible than those that have ripened and dried, though, of course, they do not yield so much nutriment, weight for weight, as the latter.

All vegetables should be so cooked as to retain their salts, or else the water in which they are cooked and which contains these salts should be used in making soup or broth, to be served at the same meal with the vegetables. This is especially advisable with regard to potatoes and sweet potatoes, as their soluble salts have much to do with their digestibility. It is for this reason that a properly roasted potato is always better than a boiled one, and that steamed vegetables are both more palatable and more digestible than those which have been cooked under water. In fact, Mattieu Williams has even suggested that possibly one reason why gout is so prevalent among Englishmen is because they habitually eat boiled vegetables and throw away the water in which these have been cooked. The salts not only help in the digestion of the starches, but they furnish bases to unite with and render soluble the irritating acids that produce the gouty symptoms. It should also be remembered that the dried legumes should always be softened by soaking in water before cooking, and that they as well as other vegetables should be cooked, whenever possible, in soft water.

Modern methods of canning afford a very efficient means of conserving great quantities of food, especially of fruits and vegetables, that would otherwise go to waste, and of extending their use at reasonable cost throughout the year. With the sanitary safeguards and precautions now employed as a business measure in these preservative processes by most responsible organizations, the products are quite uniformly of good quality and usually come to the consumer in good condition. As it is possible, however, that chemical changes may occur in certain foods

after some time, it would be well if packers were required to place the date or year of preparation on each container, while the user should give some attention to the probable freshness of the goods at the time of purchase.

Any manifest spoilage or evidence of fermentation or putrefaction of such foods, whether purchased in the market or a home product, should cause their rejection, and the evidence of any offensive odor should call for extra caution as indicating the possibility of the presence of very poisonous products of the action of the botulinus organisms.

Prepared starches, such as arrow-root, tapioca, sago, etc., are easily digestible, and therefore useful especially in the preparation of food for the young and the sick.

Fruits are especially valuable on account of their flavor, acceptability to the palate, benefit to the digestion, and for their laxative action. Ripe fruits may be eaten freely: in most cases preferably early in the day. Fresh fruits are usually better than those dried or otherwise preserved; but where the former cannot be had, the latter should be used freely, and all should be used throughout the year whenever possible. For obvious reasons, green fruit, or that which has begun to decay, should not be eaten.

Fruits are also important as components of the diet because their salts or basic radicles aid in maintaining the alkali reserve of the body and preventing acidosis, and also because many of them are rich in vitamines, especially vitamine C which is essential for the prevention of scurvy, the citrus fruits and the tomato being of particular value in this respect.

Nuts are nutritious on account of the high percentage of fat that most of them contain, but are difficult of digestion unless thoroughly masticated. Recently pastes made from various nuts have been placed on the market, and are to be considered as an agreeable addition to our dietaries.

The importance of discovering and securing the best rather than an average diet as an essential for the main-

tenance of health should be appreciated. "It is becoming constantly more evident that even a slight departure from the optimal in the composition of the food may lead to states of nutritional instability which become contributing factors to physical breakdown when hygienic factors are unfavorable, or when infectious processes are operating. Even under the most favorable living conditions, however, there can be little doubt that under such circumstances the body tissues lose their vitality and the span of life tends to shorten."[1]

As a guide to the most satisfactory type of diet, McCollum offers the following:[2] "The system of diet which can be confidently recommended with assurances that it will go a long way toward improving the physical fitness of the nation is a very simple one, and its daily practice involves no very great self-denial. It involves the borrowing of the best elements from those several systems of diet which have been thoroughly tested in human experience and have been found successful.

"The first and most important principle is the extension of the use of dairy products. Instead of the present consumption of half a pint of milk a day there should be about a quart per capita. This is a feature of the diet of all the pastoral peoples of the past and present which has made them superior in physical perfection to all other peoples. The second principle to be kept in mind is that there are dietary properties in the leafy vegetables which are unique among foods of vegetable origin. These have been the "protective foods" for many of the Asiatic peoples. Their consumption in liberal quantities as regular constituents of the diet serves not only to provide the body with valuable nutrients it cannot secure in adequate amounts from milled cereals, tubers and muscle meats, but also serves to maintain the intestinal tract in a hygienic condition through promoting elimination. Milk likewise serves, through its encouragement of the

[1] McCollum and Simmonds: The Newer Knowledge of Nutrition, 3d ed., p. 229.

[2] Ibid., p. 565.

growth of lactic-acid-producing organisms (which cause souring of milk), to bring about the disappearance from the intestine of those types of bacteria causing putrefactive decomposition of the food residues with the production of substances which are a physiological abomination. This principle, first enunciated by Metchnikoff, has been shown by bacteriological methods to be sound. Milk has dietary properties which the famous bacteriologist did not discern and which make it the one food for which there is no effective substitute.

"It is important to keep in mind the third principle of great importance in nutrition, viz., that of taking daily a certain amount of raw vegetable food for the specific purpose of providing the body with a sufficient amount of the anti-scorbutic substance. If these simple principles are adhered to, the main features of an adequate diet will be fulfilled, and the remainder of the food supply may safely be derived from any of our ordinary milled cereal products, tubers, root vegetables, sugar and meats. Infants and children can be greatly safeguarded in their skeletal development by providing them at regular intervals with a suitable amount of cod-liver oil and by affording an opportunity for outdoor exercise in sunlight."

ADULTERANTS AND PRESERVATIVES.

Much might be written concerning the adulteration and sophistication of foodstuffs and of the addition of more or less harmful preservatives to food of a perishable nature. That the first was carried on to an enormous extent seems certain. The remedy appears to be in the passage and enforcement of stringent laws and the maintenance of frequent and rigid inspection by both state and governmental authorities, in the dissemination of information as to the adulterations practised and the means of detecting them, and in the utmost publicity and exposure in the case of transgressors, all of which is now being effected by the provisions of the Pure Food and Drugs Act and the means employed for its enforcement.

This law, which became effective on January 1, 1907, provides "That for the purposes of the act, an article shall be deemed to be adulterated in the case of food: First. If any substance has been mixed and packed with it so as to reduce, or lower, or injuriously affect its quality or strength. Second. If any substance has been substituted wholly or in part for the article. Third. If any valuable constituent of the article has been wholly or in part abstracted. Fourth. If it be mixed, colored, powdered, coated, or stained in a manner whereby damage or inferiority is concealed. Fifth. If it contain any added poisonous or other added deleterious ingredient which may render such article injurious to health. Sixth. If it consists in whole or in part of a filthy, decomposed, or putrid animal or vegetable substance or any portion of an animal unfit for food, whether manufactured or not, or if it is the product of a diseased animal, or one that has died otherwise than by slaughter."

As to the use of preservatives, the very extensive sale, heretofore, of these in localities where they would be most likely to be added to food indicates their employment, as does their continual discovery by direct analysis. In Birmingham, England, such preservatives were found in 20 per cent. of 2300 samples of food examined, and boric acid in 5 per cent. of 1360 samples of milk. Such substances as boric acid, salicylic acid, and formaldehyde are commonly used, though it is frequently stated that more dangerous ones, such as hydrofluoric acid, are occasionally employed. And though it should in fairness be stated that it is possible that, if only the minimum of such substances as boric acid and formaldehyde necessary to prevent putrefactive or fermentative changes in food be used, no harm to the human economy will result,[1] yet it is undoubtedly wiser

[1] Rideal and Fullerton (Public Health, May; 1899) arrive at the following conclusions: (1) Boric acid (1 to 2000) and formaldehyde (1 to 50,000) are effective preservatives for milk for twenty-four hours. (2) These quantities have no appreciable effect upon the digestion. (3) These quantities have no appreciable effect upon the digestibility of foods prepared with them. (4) Formaldehyde in the proportion given above, so far as their investigations have extended, does not appear to have any injurious action upon animal tissues or nutrition.

to condemn the practice of adding chemical preservatives of any kind to food. There are two reasons for this: (1) There is no surety and very little probability that the minimum quantity of preservative consistent with safety to health will not be exceeded in most cases through carelessness or recklessness. (2) That foods that apparently require such preservatives should be supplied to the consumer before the deterioration in them has begun, or else they should be sterilized by the more costly but safer employment of heat.

The following diagram may be of service in determining the value of certain foodstuffs.

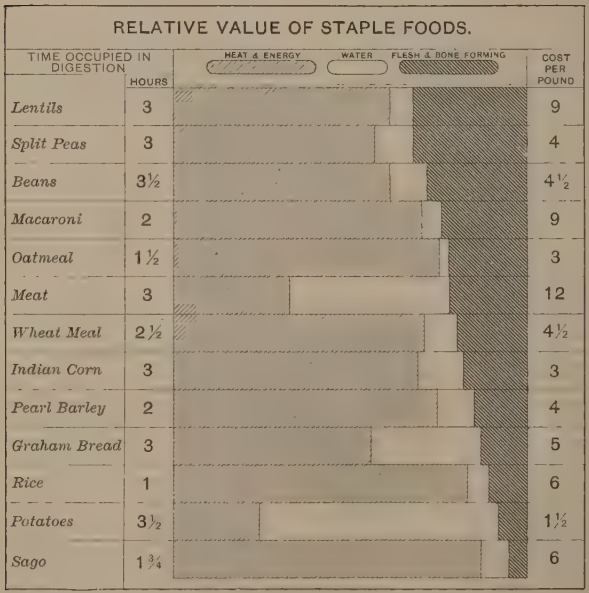


FIG. 84

CHAPTER IX.

STIMULANTS AND BEVERAGES.

The essential function and property of stimulants is to liberate some of the latent force of the body; hence they are of use and value in sudden emergencies, to tide the system over important crises, to hasten a tardy convalescence, or perchance to whip up a flagging digestion so that it may more thoroughly prepare food for the repair of waste or the supplying of body-fuel. Those stimulants, excluding drugs, with which we are most concerned are of three classes, viz., nitrogenized vegetable stimulants, such as tea and coffee; nitrogenized animal stimulants, as beef-tea and meat-extracts; and alcohol. All these are "force-liberators," and though alcohol may sometimes act the part, in more moderate measure, of a "force-producer," it is well to remember that they give scarcely anything at all to renew or replace the energy which they set free. This being so, care should always be taken that some food be supplied during or shortly after the effect produced by the agents in question, in order that the body may have a new store of force to replace that which has been liberated. Especially is this necessary in cases of sickness; and as the soluble carbohydrates furnish fuel and consequent heat and energy to carry on the vital processes, these even more than other kinds of food are to be supplied, and will generally be well received and utilized by patients or others in need of stimulation. Again, just as we must not depend on stimulants alone to the exclusion of food, so also must we take care not to continue their use any longer than is necessary to attain our object, and likewise must not overstimulate or carry the action beyond safe

and reasonable limits, but must endeavor to replenish the body energy by proper feeding, so that the body may not be left poorer and weaker in force than before the use of the stimulants began. The wise man tries to conserve his capital in bank and to replenish it as quickly as possible whenever he has to make heavy drafts upon it.

For example, "beef-tea" constantly stimulates the vital and nervous functions to greater activity, this requiring that either tissue or food be oxidized to produce the necessary energy. The stimulating factors in ordinary beef-tea are the meat-extractives, such as kreatin and kreatinin, which are products of the wear and tear of life, intermediate between living, active tissue and the final excretory matters, such as urea and uric acid; hence they can have little, if any, real food-value. Beside these the beef-tea contains only the salts of the meat, which, though valuable, are not force-producers. Therefore, unless food be otherwise supplied, the body tissue must be consumed, and the result must eventually be disastrous; and yet this is what occurs to many patients through the mistaken idea that beef-tea is both nourishing and stimulating. When "whole beef-tea" (the recipe for which is given on page 315) is used, these remarks do not apply, since it contains some true food, though even here soluble or readily digestible carbohydrates may wisely be added.

The active principles of the nitrogenized vegetable stimulants resemble very closely in chemical composition not only the meat-extractives, but also those drugs, like strychnine, which are used in medicine as tonics and cerebrospinal stimulants, and they act physiologically in a similar though milder manner.

As beverages, tea, coffee, and cocoa supply fluid for the system and that stimulation of the assimilative functions that causes a sense of comfort after their use, cocoa and chocolate having also the advantage of supplying some food. But these beverages may all be abused in their use as readily as may beef-tea or alcohol, and "tea-drunkards" and "coffee-drunkards" are not uncommon in hospitals

and in private life. The teacup is not always the one that "cheers but does not inebriate." Women especially who drink much tea are apt to be nervous and dyspeptic, to have the "tea-drinker's heart," and to suffer from headaches and neuralgias. They depend upon tea to take the place of nutriment, and soon use up what little store of force they may have had, since they fail to replenish it with fuel-food. Men are more addicted to the use and abuse of coffee, and often manifest symptoms directly traceable to such intemperance. While caffeine increases heart action, and may be used to advantage in cases of cardiac debility, for the same reason it should be taken with caution and in moderation where the cardiac action is already too vigorous. Vogel has advised the use of strong coffee with sugar and cream as a tonic and food in debility accompanying the acute diseases of children.

It is interesting to note that among all nervous, energetic people the use of some one or other of these stimulant beverages is common, and that "total abstainers" from alcohol seem instinctively to resort to tea or coffee. And while it is probably theoretically true that the healthy person would better abstain entirely from the use of stimulants, except in emergencies or at rare intervals, yet the almost universal desire for and use of them probably indicate that under our present high tension of living there is a real physiological demand and need for them that perhaps should be satisfied in a measure, but with moderation and judgment."

ALCOHOL.

Liebig says that "alcohol stands only second to fat as a respiratory material," but adds that "the same effect could be produced in the body by means of saccharine and farinaceous articles of food at one-fourth or one-fifth the cost." Fothergill also holds "that the chief portion of the alcohol ingested undergoes consumption in

the body," but insists that "the question of 'alcohol as a food' can never be separated or divorced from that of 'alcohol as a stimulant' or as a force-liberator."

Much undue importance has been given to scientific investigations that served to establish the fact that alcohol can be, and often is, almost completely oxidized in the body, and that it produces therein practically the same number of heat-units as when it is consumed outside. But the inference that it can therefore be substituted for, and used with impunity in place of the usual carbonaceous foods is not justifiable, because the powerful physiological and ultimate pathological effect of the alcohol upon the higher nerve centres and active tissues is ignored, because of the liberation of the body's latent force in excess of the energy which the alcohol supplies, and because even the above-mentioned investigations and experiments went to show that there was an actual detriment to the nitrogen-bearing tissues of the body during its use.

Again, Liebig writes that "the use of spirits is not the cause but the effect of poverty. It is the exception to the rule when the well-fed man becomes a spirit-drinker. On the other hand, when the laborer earns by his work less than is required to provide the amount of food which is indispensable in order to restore fully his working power, an unyielding, inexorable law or necessity compels him to have recourse to spirits. He must work; but in consequence of insufficient food a certain portion of his working power is daily wasting. Spirits, by their action on the nerves, enable him to make up the deficient power at the expense of his body; to consume today that quantity which naturally ought to have been employed a day later." This may also be the case where there is an abundance of food, but where it is improperly chosen for the needs of the individual or ruined by bad cooking. Education in the principles of the scientific and economical selection of food and its preparation may thus become a means of preventing those diseases that

depend on, or are aggravated by, insufficient or improper food and consequent alcoholic excesses. The effect of alcohol upon the weak and savage races is much more marked and disastrous than upon the civilized and strong; so it harms the health of the underfed and overworked much more than it does that of the well-fed man of means and leisure, and affects women and children more than adult men. This latter point is to be remembered in practice.

Remember also that, while alcohol is partially a respiratory stimulant, it is a force-liberator and consumes the body-store, and unless given with other readily oxidizable food the risk is run of putting a patient "in a grave never dug by Nature," especially where there is already danger of the patient sinking from exhaustion. But it is just in these cases, when given with other food, that we find alcohol a valuable therapeutic agent. Give it with foods that produce heat and force—*i. e.*, with some form of the soluble carbohydrates, as maltose, malt-extracts, milk, milk-whey, or even sugar. Where the assimilative powers are weak it may be advantageous or necessary partially or wholly to predigest these foods; but above all, remember to replace what alcohol takes from the body, or physiological bankruptcy will ensue. Note also that, though alcohol may be in one sense a food, it is a very costly one, and that intoxication must occur long before a man could get the equivalent of a full meal.

Alcohol is to be used in sickness practically to sustain the vital powers, to meet emergencies, and to lift the patient over obstructions in the road to health; and such use requires a thorough knowledge of its action coupled with the highest judgment. It should also be noted that there is an increasing tendency on the part of the medical profession to prescribe alcohol much less frequently and more sparingly than was formerly the practice.

In malt liquors there is usually considerable maltose, thus combining with the alcohol a soluble carbohydrate of the highest value, and these brewed ales, etc., may sometimes be used with benefit as tonics, especially where con-

valescence is protracted. The stronger distilled liquors are diffusible cardiac stimulants, and are possibly valuable in emergencies, but the continued use of them must only be advised with great caution.

Fothergill gives two excellent rules for the use of alcohol by the healthy: "First, never have alcohol in the brain when it has work to do; second, a little alcohol betwixt a a man and past trouble is permissible; but it is not well to put a little alcohol in front of a coming trouble." Murchison, in his work on *Fevers*, lays down these rules for practice, which it would be well for all to adopt: "What are the conditions of the animal economy in which alcohol may be of positive use? That there are such conditions, I believe cannot be denied by anyone who has honestly studied the subject; but they are not the conditions of perfect health. It is especially when the circulation is weak or sluggish that a daily allowance of alcohol may do good. Thus: (1) Alcohol is useful in the course of most acute diseases when the organs of circulation begin to fail, as they are apt to do. A moderate quantity usually suffices. The large quantity still sometimes administered may do harm by inducing congestion of internal organs. (2) In convalescence from acute diseases or from weakening ailments, when the circulation remains feeble and the temperature is often subnormal, alcohol is useful in promoting the circulation and assisting the digestion. (3) In persons of advanced life the circulation is also often feeble, and a moderate allowance of alcohol often appears to be beneficial. All other conditions of the system marked by weakness of the muscular wall of the heart, whether permanent or transient, are usually benefited by alcohol." Alcohol may thus be of value in forestalling or overcoming the depressing influences of the toxins produced in certain of the infectious diseases, and in shock. In the latter, however, especially when due to accident or to some sudden cause, much harm rather than good may be done by the administration of excessive doses of alcohol, on account of their effect upon the depressed vital centres,

and it is well to remember that better and speedier results will probably follow small doses sufficiently frequently repeated.

Alcohol is a good servant, but a bad master. King Chambers says: "Let alcohol be taken never as a stimulant or preparative for work, but as a defence against injury done by work, whether of mind or body. For example, it is best taken with the evening meal or after toil. Let the increase in the desire for, and the power of, digesting food be the guide and limit to the consumption of all alcoholic liquids. Let the forms be such as contain the least proportion of fusel oil. Let all with an hereditary tendency to hysteria or other functional diseases of the nervous system refrain from its use altogether, even though as yet in good health."

BEVERAGES.

To comment individually upon the multitude of non-alcoholic and non-stimulating beverages that are now more or less generally used, is both impracticable and unnecessary, nor will any attempt to classify them be of much value. For the most part they serve only to please the palate; though if in this way they bring about a greater ingestion of fluids when these are needed, their service cannot be considered a vain one. For it has already been stated that an ample supply of drinking-water or other fluids taken daily and habitually is essential to the satisfactory removal of the various waste matters from the body, and that without it the latter may readily develop conditions favoring disease.

Moreover, it is true that certain gases and salts held in solution in some beverages, such as mineral waters, increase this excretory action, and may be highly beneficial in appropriate cases; but it should be a matter of caution that where such therapeutic results are thought to be necessary, competent medical advice should be the guide as to the kind and quantity of the agents used.

This comment is justified by the fact that of late many substances capable of influencing the body functions have been advertised and sold in the form of one beverage or another directly to the laity, who, being incompetent to judge as to whether or not such substances are actually needed in their individual cases, may in this way do themselves much harm.

Only such beverages, then, as are quite simple in their nature or are advised by competent medical authority should be used. If they are artificially made and water is the solvent fluid, as it will be in most cases, there should also be a certainty that it comes from a clean and safe source, lest it carry the germs of disease. There is no doubt that frequently the cheaper bottled drinks which are dispensed so generally are made from water that has been liable to more or less dangerous pollution, and there is the additional risk that arises from the imperfect cleansing of the bottles for these liquids which have been returned to be refilled. A little thought as to the dangers which do exist in relation to this matter will be convincing as to their gravity.

Many of the most popular beverages are charged with carbon dioxide under compression, and the fact that so much of this gas can be taken into the system in this way without apparent harm, and its free elimination, would seem to be additional evidence that it cannot in itself be so very harmful in the atmosphere, even when in proportions considerably greater than the normal.

In conclusion, it may be said that a free use of all such beverages as are known to be clean, safe, and wholesome will probably be found to be entirely favorable to health unless there be some contra-indicating reasons peculiar to the individual himself; and that their substitution, whenever possible, in place of the alkaloidal and alcoholic stimulants is to be commended on hygienic as well as other grounds.

CHAPTER X.

PERSONAL HYGIENE.

The proper consideration of this subject demands an ample volume rather than the limits of a single chapter, for the ultimate aim of all sanitary work is the preservation and betterment of the health of the individual; moreover, the factors that affect the well-being of the person are so multitudinous in their number and in their phases that no brief discussion can comprehend them all.

However, much that pertains to personal hygiene and that requires no repetition for its application has already been given in the preceding pages; so that it is hoped that if the reader will exercise that virtue of common-sense and reflection that is so essential in this study, the remarks to be added will be helpful in suggestion and in answering many questions, even though they may not be considered in any way as complete discussions of the respective themes.

Each age has its own requirements, and that which may be entirely satisfactory or permissible at one time may not be so at another. To attain the best results it will often be necessary even to anticipate with prophylactic measures the birth of the child; and, broadly speaking, much of the welfare of future generations lies in the care of those now living.

One of the gravest sociological problems of the day is as to how far the State is justified in restricting or preventing the propagation of the defective or degenerate of the human race; and though the time may not be ripe for the law to take positive action in these matters, it is the duty of every sanitarian to use his utmost efforts to the end that only the healthy and the normal may continue.

The advances in physiological and biological science in recent years have done much for all humanity, but in no respect, perhaps, have they been of more service than in determining the great influences of heredity, habit and environment and in establishing the fact that the presence or absence of disease is oftentimes, due as much to predisposing conditions and the physical status of the individual as to external and exciting causes. What may cause only a trifling ill in one may bring about most serious evils in another whose estate is not so fortunate.

Life has been defined as the power of an organism to adjust continually its internal conditions to its external conditions, and as long as this is satisfactorily done life persists. The secret of personal hygiene and health, then, must lie in determining the relationship between the internal and external conditions of the individual's organism.

Thus, as Hill says, the *new* hygiene "deals with the reactions of the body to its surroundings," and "life has become what it is today, the most wonderful thing in the world, by the adjustment of life to things, rather than the adjustment of things to life."

"Know thyself" is advice good for the body as well as for the mind or soul, and knowledge of the right kind can do no harm. He who knows his personal and physical nature and acts accordingly is well equipped to fight against the ills of life, and the study of the relationship above referred to will help the thinking man so to care for himself that in all probability his days will be prolonged.

But a caution or two must be interpolated here. It is well known that "expectant attention" too persistently directed toward a particular organ may lead to decided alterations or disturbances in the functions of that organ; and again, unless one well understands the mysteries of human physiology, a little imperfect or insufficient information in this respect may lead to the assumption or pursuit of habits and practises actually dangerous to health. Too much ill-advised care and attention may be just as

full of risk as too little, and physiological egotism without a sound basis may have a bitter reward.

What is needed is that each one should study carefully the phenomena of his daily life, should determine accurately the purpose and reason of each of the respective functions, and then, not forgetting their interdependence upon one another and that all should work in harmony, should endeavor to do that which will best facilitate the functional activity with the least expenditure of energy.

There are a number of ways in which the study of personal hygiene may be advantageously pursued, but for practical purposes one of the best is to consider it with respect to the main groups of organs and functions of the body, keeping always in mind, however, the correlation of these, and that no part of the body can be entirely independent of the rest.[1] Nevertheless, the hygiene of infancy and childhood is a study by itself, for it is in that epoch of life that the plastic constitution can be and is molded most readily by all the influences of the environment, whether for good or evil, and it is at that time that salutary efforts are to be made with greatest hope of success and eventual good.

Moreover, the principles of personal hygiene may be more readily taught to, and inculcated in, the young, but with much greater difficulty can we affect the mature or aged; for we are all creatures of many habits, and in the mature adult the impress of these may resist to the utmost any and all endeavors to modify or remove them.

Too much stress cannot be laid upon the fact that it is the constitution, the nature of the inherent tissue, that controls or modifies the inception, development, and progress of many of the ills of life, and that whether this in

[1] This method has been followed in Pyle's Manual of Personal Hygiene, to which the reader is referred for an admirable discussion of the subject, which must be treated all too briefly here. The writer would also recommend Griffith's Care of the Baby to all who desire specific and authoritative information concerning the very young.

its normal and highest vigor be a bequest of heredity or be attained only by the most careful attention to details in the practice of the art of hygiene, it should always be looked upon as the most valuable physical possession of the individual.

To state again what has already been written: "The essence of hygiene and sanitation is to secure perfect health, to increase the inherent power to resist noxious and harmful influences, and to make all the surroundings and environments of the body pure and free from depressing factors."

With this preface, the following discussions are added in the hope that they may be of assistance in determining the way of right living and in securing the welfare and health of each individual.

HEREDITY.

In the broad biologic sense, heredity is the transmission of a series of characteristics to and by a fused cell, formed from two cells furnished by respective parents, which carries on its evolution under certain governing impressions indelibly stamped by the two parental lines of descent; but, in the ordinary use of the term, it may be defined as the transmission to the offspring from parent or ancestor of any trait, type, temperament, characteristic, or predisposition which has a governing or influencing effect upon the growth or nature of that offspring. These transmitted impressions may be either for good or for evil.

"Individuality, hereditary traits, sex—all these, we may be sure—are unalterably determined from the moment of conception. The germinal cell forms the total contribution of the male parent to pregnancy; thereafter no other opportunity for him to influence his progeny presents itself, and the substance which enters the ovum at the time of fertilization must be the basis of inheritance from the father. It is equally true that the nucleus of the ovum and the nucleus alone transmits maternal

qualities. The material which conveys inheritable characters can be seen and has been identified in both germinal cells; from each of them the fertilized ovum derives equal amounts."[1]

"It shows an incorrect conception of the law of heredity to look for a return of identical phenomena in each new generation."[2] Also, "we do not mean exclusively by heredity the very complaint of the parent transmitted to the children, with the identical symptoms, both physical and moral, observed in the progenitors. By the term heredity we understand the transmission of organic dispositions from parents to children."[3] In true hereditary disease the faulty conditions must be transmitted in the *germ-plasm*, and not be due simply to accidental factors affecting the embryo during its fetal development, the results of the latter being *congenital* rather than inherited.

It apparently has been definitely established that the chromatin of the nuclei of the germinal cells is the particular material or substance by which inheritable characters are transmitted from parent to offspring. Just prior to cell-division this chromatin breaks up and rearranges itself in the form of rods of varying shapes and sizes called chromasomes, each species of animal having a definite and uniform number. Moreover, in the study of lower animals and insects, careful students of this subject have been able to identify certain chromasomes of definite shape and appearance as the constant carriers of certain transmissible characteristics.

For the human the special number of chromasomes is twenty-four, but before the union of the male and female germinal cells these are reduced in each to twelve, so that the fertilized ovum contains the characteristic number of the species instead of twice as many. "While we know nothing of the forces which determine, on the one hand, what elements shall be discarded by the germinal

[1] Slemons: The Prospective Mother, p. 28.
[2] Moreau, Psychologie morbide.
[3] Morel, Traite des Dégénérescences.

cells and, on the other hand, what elements shall remain, it is definitely proved that a selective process always takes place. This fact admirably explains the variation in the characteristics inherited by children in the same family. So far as is known, the traits which will be passed on from either parent is a matter of chance. Whatever these hereditary traits happen to be, the best evidence we have indicates that the problem of a child's inheritance is settled once for all the moment conception takes place."[1]

Consequently, as hygienists, we must use the influence and power that we have to further the transmission of only beneficial or elevating characteristics, and to prevent the bequest of harmful influences and hereditary diseases to the generations to come. "The germ of the unborn infant must be complete and untainted in all its nature, otherwise we cannot hope for a vigorous and perfect growth or development."

As the family is the foundation of the State, and society is a congregation of men for the purpose of acquiring greater power and more comforts through mutual co-operation, the latter, whether domestic or civil, has some right to make men understand that they must care for the health of the generations to follow, and to enact reasonable laws looking to the prevention or obliteration of transmissible infirmities. And history seems to show that no great nation has ever been destroyed or overwhelmed until its people had first neglected or abused the laws of hygiene, heredity, and sociology.

MARRIAGE.

We find that a married couple have generally, beside themselves, the welfare of from three to five human beings within their keeping. To produce healthy children and ones not prone to disease, both parents should possess good constitutions, and they should take great care not to

[1] Slemmons: The Prospective Mother, p. 67.

weaken these by excesses of any kind, physical or mental, nor, as far as lies in their power, by any chronic disease. It is evident that children of parents that have been conscientious observers and followers of Nature's laws must have a better chance for health and superiority all their lives.

In this climate the proper age for marriage is considered to be about twenty-four or twenty-five for the man, and nineteen or twenty for the woman, though this must vary with the state of development of the parties concerned. Some of both sexes mature at a considerably earlier period than do others, and it would be unjust to say that they were not fit for the duties of marriage till they reached the age of the maturing of slower-growing ones. Usually, however, before the ages given, development is not complete and the whole organism is in a transition state. We know that the use of any organ before it has attained its complete growth or development is very apt to cause exhaustion or, perhaps, premature degeneration of that organ, and we cannot but believe that children developed in immature sexual organs must be deficient in vital force and energy. It is often noticeable that a child apparently strong and vigorous may have but little power to resist disease or may even be strongly predisposed to some infirmity; in such cases there will likely be some defect or taint in the parent stock.

Distinguishing characteristics are more likely to be transmitted in the early married life of parents, because their organs and forces are then more vigorous; but if a couple marry when quite young and before their own organs are fully developed, their elder children may be more deficient, mentally and physically, than their later ones.

Late marriages are not likely to be so fruitful as earlier ones, possibly owing to the increased difficulty of parturition on the part of the mother and her consequent unwillingness to undergo the ordeal more than a few times. But healthy middle-aged persons, who have married late,

may have even healthier children than those who have married too early.

Some authorities hold that in features, constitution, sense-organs, shape of head, etc., the child is most apt to resemble the father; while it will likely follow the mother in the shape of the trunk and in the formation of internal organs. The character and mental qualities of the child may come from either parent or from both. Habits, or conditions during pregnancy, especially if continuous or persistent, undoubtedly may have a marked effect upon the coming infant. So also do maternal toxemias or other depraved conditions of the mother's system, though occasionally such influences apparently do not do as much harm as we would anticipate. There may, however, even be actual and direct infection of the child through the placenta. In fact, "intra-uterine infections and modifications of the fetus are more frequent and more important than conditions of true inheritance of disease."[1]

INHERITED AND CONGENITAL DISEASES.

Hereditary influences are generally transmitted directly from parent to child, but we occasionally find a cessation of a trait or predisposition for one or more generations and then a recurrence. To such a peculiarity we give the term *atavism*. "A family history of less than four generations has only a limited value."

An hereditary malady may be actually existent at birth and be transmitted directly from parent to offspring—as syphilis, structural deformity, mental or nervous defect, etc.; or there may only be an inherited predisposition to the disease, as toward tuberculosis, etc. Physicians have thus a twofold duty: first, to do all they can to guard against the transmission of such diseases; second, to combat the disease or any tendency to it as soon as the first symptoms thereof are discovered or it is suspected in

[1] McFarland.

the child. The first duty can be accomplished, theoretically, by preventing generation and production on the part of those unfit to produce healthy offspring, and practically, within certain limits, by fighting the causes and their effects in the parent individual, especially at the ages or times when these have the greatest force or are most apt to manifest themselves. For the second, the child must be immediately placed in the most favorable hygienic surroundings, and everything possible done to prevent the further development of the disease or predisposition. In many cases such early interference will

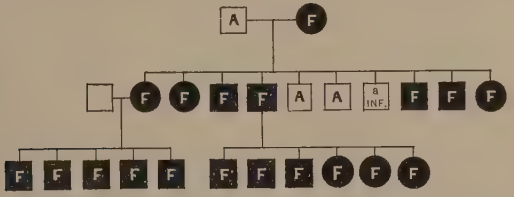


FIG. 85.—Eighteen feeble-minded children and grandchildren. A feeble-minded woman married an alcoholic man. Seven of their children were feeble-minded, two were alcoholic and one boy died in infancy. Two of the children (both feeble-minded) have children. All eleven were feeble-minded. Squares are males, circles are females.[1]

accomplish much good, and the disease may be averted entirely. Especially is this true of those inheriting the tuberculous diathesis.

Too often the child of a tuberculous parent is exposed after birth to the same conditions that served to develop the disease in the parent, and its inherited predisposition to the malady is intensified by the environment of a damp and undrained soil, a dark and unventilated house, etc., and by insufficient or improper food, until infection is all too easily acquired, and the child that might have

[1] Figs. 85 and 86 are from a Bulletin on The Transmission of Feeble-mind, issued by the Department of Public Health and Charities of Philadelphia, 1910.

been saved becomes an early victim of the ignorance, carelessness or neglect of those who should have fostered it with extremest care and solicitude. On the other hand, the apparently complete eradication of the transmitted predisposition from many children whose inheritance has been as bad, but who were promptly removed from the unsanitary environment of their birth and given proper hygienic care and training, shows how much this one influence may work for good.

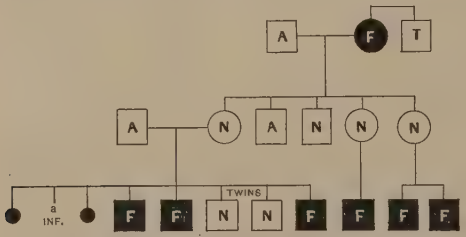


FIG. 86.—Second generation apparently normal (six feeble-minded appear in the third generation). A feeble-minded woman, possessing a tuberculous brother, married an alcoholic man. Result, three (apparently) normal girls, one normal boy and one alcoholic son. One of the girls married an alcoholic man. Three feeble-minded sons, two normal sons (twins), two miscarriages and a child dying in infancy resulted. The other two, apparently normal girls, each produced feeble-minded offspring; one a boy, the other, two boys. Squares are males, circles are females. Small black circle indicates miscarriage. This chart also illustrates atavism in its relation to feeble-mindedness.

The most important of the supposedly hereditary or transmissible affections are syphilis, tuberculosis, gout, hysteria, epilepsy, certain physical deformities, certain skin diseases, insanity, feeble-mindedness, and criminal tendencies of various kinds. But do not forget that what may appear to be a direct and actual inheritance of a disease may only be the production of the disease in that person by the same agents, environments, and morbid conditions as caused or favored the disease in the parent. However, even here there is very possibly

a transmitted predisposition to the acquirement of the disease, rendering it all the more easy for it to develop and to manifest its symptoms upon slight provocation. Therefore there should be no marriage between persons inheriting predispositions to the same disease, especially if they be relatives, and "a person affected with hereditary or well-marked constitutional syphilis, or having a strong consumptive taint, or tendency to mental unsoundness (or weakness) should not marry at all."

Defective eyesight is very apt to be transmitted to children, and the latter should be carefully examined and, if necessary, fitted with proper glasses before being placed at school or at any work requiring much use of the eyes.

Infirmities which do not prevent marriage from being fully accomplished, or which do not tend to the degeneration of the offspring, are not good reasons alone for forbidding marriage, but all that have such a tendency are. A man should not marry a woman too far advanced in life, nor one that is very feeble, delicate, or deformed, especially as to the chest or pelvis. Hysteria, convulsions, and epilepsy due to organic disease should prevent a woman from marrying, though some extremely nervous and hysterical women are much benefited by marriage and have healthy children. So with many women who have uterine congestions and displacements before marriage.

Evidence seems to indicate that marriage between relatives is reprehensible, and that the danger increases with the nearness of the relationship, since the children of such marriages are prone to disease and to defects in the sense-organs, especially the eye and ear, or in mental qualities. But upon closer investigation it is probably more nearly true that "the objection to consanguineous marriages lies not in the bare fact of the relationship (of the parties concerned), but in the fear of their having similar vitiations of constitution." Few families or persons are absolutely healthy or free from taint, and "it may safely be asserted

that when both parents are possessed of a physiological or pathological congenital characteristic, that characteristic is almost certain to be repeated in an aggravated form in the offspring."[1] We can, accordingly, easily understand that "in consanguineous marriages the real danger is in the strong probability that both parents have some distinct taint of degeneration, which is liable to be increased in their children, but which might possibly disappear if each married a person not bearing the same or some closely allied character. The marriage of two individuals of the phthisical type, whose families were strangers to each other, would be as productive of evil as the marriage of first cousins who were phthisically inclined."[2] However, any advice on the subject must depend upon the special circumstances in each case, but chiefly on the health and degree of relationship between the parties.

PRENATAL HYGIENE.

The realization that by the proper care and guidance of the prospective mother much could be done not only for her own welfare but also that of her unborn child has resulted in the study and development of the principles of prenatal hygiene. This volume is not the medium for and space does not permit the adequate discussion of these, but it may be well to call attention to certain matters of importance to women in the state of expectant motherhood.

Obviously, everything possible should be made subservient to the welfare and best interests of her who from the moment of conception has already undertaken and begun her maternal duties. She should have proper and sufficient food, exercise and rest, there should be no undue fatigue nor harmful disturbance of mind or body, and there should be constant care to protect her from accident or shock that might result disastrously to her or the child.

[1] Lawrence Irwell, Philadelphia Medical Journal, July 21, 1900.
[2] Ibid., July 28, 1900.

As regards her diet, there will be, contrary to common opinion, no necessity for an increase in quantity except possibly in the later months of pregnancy, and then only in respect to the carbohydrate principles; but it will be well for her to give attention to the quality of the food she eats, especially with reference to the proteins and the vitamines that will have so much to do with the health and longevity of her baby. There should be no attempt to lessen minerals in order to "keep the baby's bones soft," not only because of the risk of a rickety child, but also because Nature will try to take the minerals from the mother's own body when her food does not contain a sufficiency for the child. Care must also be given to keeping the digestive functions at their best and to doing everything possible to lessen the work of the excretory organs. Above all plenty of fluid must be taken to maintain the function of the skin and lessen irritation of the kidneys, and there should be regular examinations of the secretion of the latter by a competent physician, especially in the later months of the pregnancy.

The rule as to the avoidance of undue fatigue must be made as near absolute as possible, and women who are employed in arduous labor outside home should be freed from it for several weeks before and after the birth of the child. On the other hand, there should be enough agreeable exercise of some kind or other throughout the period to keep the body in excellent physical condition and at the same time favor the best development of the embryo. But no violent or risky sports or enterprises should be indulged in that might result in a miscarriage or endanger the physical safety of the child.

Attention must also be given to bathing, not only for cleanliness but as a means of stimulation and relieving the kidneys, and to proper clothing with regard to warmth, comfort and safety for the child. Likewise, a confident mental attitude and cheerfulness of spirit is to be fostered, and above all a vigorous determination to do whatever will aid in giving a sound body and healthy constitution

to the new being. To ensure this the prospective mother should engage the services of a competent physician soon after becoming aware of her pregnant condition, and should consult him promptly concerning anything about herself which she does not understand.

With such prenatal care experience is showing in hundreds of cases that not only is the safety and comfort of the mother conserved, but that the chance of living and of good health for the child is much enhanced. It is one of the fields of modern hygiene not only full of promise but already yielding a big harvest.

It is scarcely necessary to add that it is also not only advisable but even essential to the social good and public welfare that women who have recently brought children into the world should have the best of care and protection until they have again regained their health and strength, and especially to the end that they may be able to nourish and care for their offspring in the best possible manner. Thus the subject of Postnatal Hygiene is also one of paramount importance deserving its full share of study and interest, even though it be outside the scope of this work.

HABIT.

We are apt to consider and frequently to state that an individual is what he is because of two chief factors, heredity and environment, and consequently to believe that the status of his health at any time is largely due to these important influences. In doing so, however, we overlook another force—that of habit—that often is almost if not fully equal to either of the others in determining one's condition and his ability to meet and resist the enemies of his physical welfare. As some one has said, "in the cradle lies the foundation of regularity in habits and the responsiveness to sound habits." But few infants in the cradle get this training for sound habits, and from infancy on through childhood adolescence and the whole of life the development of habits, good or bad,

is largely a matter of chance. This is because most parents are untrained and do not appreciate the importance of the tendencies that are developing in and moulding the bodies and functions of their children, and that may bring results that, however harmful, may be almost ineradicable.

Fortunately for the coming generation the modern health supervision of our schools may lead to the detection and possible correction of some of the bad habits that are developing, and many parents are willing and eager to give their best efforts to this end when their attention is properly directed to the evils that threaten their offspring. Moreover, the interest of the children themselves in good health is aroused and the desire for strong and healthy bodies becomes a paramount interest in their lives that will not be lost as they grow older. So, with the opportunities for the removal or correction of physical defects, such as bad teeth, adenoids, poor eyesight, etc., that are so freely available in most of our larger communities, we have reason to believe that the youth of the years to come will be able to have and to maintain a higher health level than the generation of today. They themselves may and, it is to be hoped, will pay more attention to the development of proper habits of living and thus can avoid many of the ills that threaten and beset the more careless now.

As has already been stated, the human life-span has been markedly lengthened in recent years, but careful study of the effective influences through which this gain has been made show that they are chiefly those that affect infant mortality and the removal of the risks to which the young are especially liable. The mortality-rates for many of the maladies that occur mainly in those of advanced age are not decreasing but in some cases are actually and progressively increasing, and investigation is showing that some, at least, of these latter diseases are such as have long-continuing and faulty habits as causative factors. Some of these habits are within the conscious domain of the individual, such as those that pertain to posture, exercise, sleep, choice of food and drink, manner

of eating, temperance, continence, etc., and some are subconscious habits of organs and functions related to or affecting assimilation, excretion, coördination, etc. Also, "it is highly important to realize that we have emotional habits as well as habits of mind and body," and that these, too, may in due time affect one's state of health.

After the lapse of years such faulty habits may be very difficult to amend or even practically ineradicable, although the harm that they may do may be fully appreciated. It should be remembered, however, that all are under control at the beginning and that a rightly planned order of living will prevent their development and the subsequent troubles due to them. One of the greatest reasons for the regular and thorough medical examinations which every individual should have made, at least annually, is that by this means detrimental habits may be detected in their incipiency or before they have become fixed or done irreparable harm. By this means an intelligent person can and will take stock of himself and so adjust his living that he may reasonably look forward to a hale and happy old age, untouched by many of the discomforts and disorders that plague his more careless or reckless contemporaries.

Habit, therefore, has much to do with the making of the individual and the state of his health from infancy on to his death. It may be as potent in shaping his physical destiny as either heredity or environment and should be classed with these as one of the governing factors of life. Parents should be watchful regarding the habits of their children from the earliest days of infancy and should maintain the supervision until the adolescent has judgment enough to map out and follow his course for himself. Moreover, it is the duty of health officers to inculcate and stress in schools and elsewhere the importance of good health habits and to do everything possible to foster their development. This is a field of service co-equal in some respects with sanitation, the study of environment, and with that of heredity, which is a matter of hygiene as this is.

EXERCISE.

Exercise is generally considered to mean simply the action of the voluntary muscles, but it has a wider meaning than this. Every organ in the body is capable of being exercised in some way or other; and if not properly exercised, an abnormal state is almost certain to ensue. "Life is organization in action." Each organ has its own special stimulus, and if this be normal in amount and character, we should have health. Also, the trained use of an organ makes it more effective in the performance of its functions. But deficiency in exercise favors a lack of nutrition, wasting in size, and eventually degeneration of tissue; while, on the other hand, too much work may favor hypertrophy and tissue degeneration.

Proper muscular exercise is highly beneficial to health, and in the end actually necessary to the proper performance of functions in other organs; it is consistent with and necessary to health. But, to be of value, the exercise must not only be regular, but must also consist of movements of sufficient force to necessitate energetic contraction of the muscles; we must do work. This necessitates resistance as an element, and we may define physical exercise as *voluntary labor*. We need the resistance to obtain the proper contraction of the muscles, the contraction for their disintegration, the disintegration for their renewal, etc.; for we know that upon the constant destruction and disintegration of tissues depends their subsequent renovation, and that the strength and vigor of all parts of the body and of the whole body depend upon its *newness*.

Beside the fact that proper physical exercise makes the voluntary muscles larger, harder, stronger, and more quickly responsive to the will, and that it increases the functional capacity of the involuntary muscles employed, it largely promotes health and strength by quickening the circulation and increasing the respiratory powers. During muscular action (contraction) there is a conversion of

potential energy into motion, a call for more food, an increased demand for and consumption of oxygen, and an increased production of and elimination of carbon dioxide and other waste matters.

This increased demand for oxygen and elimination of carbon dioxide necessitate increased action of the respiratory organs—the lungs, and this is one of the greatest advantages of physical exercise. The respirations are increased in frequency and depth, the lungs expanded, the air vessels flushed out and refilled with each inspiration. Doubtless many cases of pulmonary tuberculosis could be prevented or cured if only people could be taught to take sufficient and suitable exercise and to breathe properly, for we rarely find the lungs fully expanded except in the outdoor worker or athlete. Consequently, the movements of any given exercise should be with speed and force sufficient to quicken and deepen the respiration; and, conversely, if any severe exercise is to be undertaken or a course of training begun, special care must be had to develop the lung capacity.[1]

A man exercising, even moderately in any manner, inspires considerably more air than when reclining at rest, which latter amount is, for an adult, about 480 cubic inches per minute. Or, as Pettenkofer has shown, a man on a day of rest absorbs 25 ounces of oxygen and throws off 32 ounces of carbon dioxide and 29 ounces of water; on a day of work he absorbs 33.6 ounces of oxygen and throws off 45 ounces of carbon dioxide and 72 ounces of water. In other words, the elimination of carbon on a work-day is more than three-fourths of a pound.

Muscular exercise is necessary, therefore, for the proper elimination of waste carbon from the body, and, as the action of the muscles is checked and lessened if the

[1] The caution, however, should be given here that persons with incipient tuberculosis, or with a marked tendency thereto, should not take up exercises involving deep and rapid breathing, except under the advice of a competent physician, as much harm may result in some cases from such unwonted excitement of the pulmonary tissue.

carbon dioxide produced by their action is not immediately carried off by the blood and eliminated by the lungs, it follows that during exercise there should be nothing to impede the circulation or the action of the chest and lungs, and that all tightness of clothing, especially about the waist, neck, and chest, should be avoided. Moreover, inasmuch as the amount of carbon dioxide and other waste matters eliminated is so very much increased during exercise, a much larger amount of pure air is needed, and all rooms and buildings wherein exercise is to be taken should be well ventilated.

After exercise an increased amount of carbonaceous food and of water must be supplied to replenish the system for what has been eliminated. The increase of carbon food is probably best given in the form of fat rather than of the carbohydrates, though there is some difference of opinion on this point; and of all fluids, water is doubtless the best in ordinary cases for training. As a general rule, alcohol is harmful, because it benumbs and deadens the nerves and will, and because, as every voluntary impulse must originate in the brain, anything that interferes with the communication between it and the muscles must lessen the promptness with which they respond and the consequent efficacy of their work. The advanced opinion of today seems to discountenance the use of alcohol in any form or at any time by those in training for contests of skill, endurance and strength.

By exercise the action of the heart is increased in force and frequency, the pulse is made full and strong, if the work be not too excessive or sudden, and the flow of blood and other fluids is increased throughout the whole body. As long as the heart is not overtaxed the pulse-beats are regular and even, though suddenly increased exertion may make the rate very rapid. Ordinarily exercise increases the rate from ten to thirty beats per minute. Excessive exercise leads to palpitation and hypertrophy of the heart (one reason why any extensive training should be under a competent trainer); but, on the other

hand, deficient exercise leads to a weakening of the heart muscle and heart action, and probably to dilatation and fatty degeneration. If at the beginning of a new exercise the heart action becomes irregular, rest should be taken, and the exercise then begun in a more moderate and gradual way. The heart stimulus is largely due to the increased amount of blood in its cavities, but it should be remembered that the venous circulation is chiefly due to the muscles. "Every muscle is a little heart," and these, by their contraction, constantly tend to drive the blood onward to the true heart and lungs.

Exercise greatly increases the amount of perspiration from the skin, this perspiration containing water, salt, and considerable waste matter. The evaporation of the water tends to keep the body cool, but on account of the great heat-production there is not much danger of chilling the body during exercise. As soon as work is stopped heat-production is checked, the body cools off rapidly, especially in a strong draught or current of air, and then there is danger of chilling unless more clothing be added. Flannel is best for this purpose because it is a non-conductor of heat and hygroscopic and so prevents too rapid cooling of the body. Keep the skin clean so that the sweat-glands may be unobstructed in the performance of their functions.

Exercise increases the appetite, partly because of the increased demand of the muscles for food, and partly on account of the increased circulation of the blood through the vessels of the alimentary tract, digestive glands and the liver, this causing a more perfect digestion of food.

If exercise be taken too soon before meals, either the stomach, by calling the blood from the exhausted muscles, will prevent their proper repair and rest; or the muscles, calling the blood from the stomach, will prevent the proper formation of the gastric juice when food is introduced. If exercise be taken too soon after eating, it is apt to prevent the flow of blood to the organs of digestion and the formation of the digestive juices; or, by forcing

the contents of the stomach into the intestines before gastric digestion is completed and before the food has reached a condition in which the intestines can make use of it, to cause intestinal irritation and indigestion.

Proper physical exercise favors a symmetrical brain development, for it not only sends more blood containing food and oxygen to this organ, but exercise of the functions of the centres governing the action of the muscles must also favor the growth and development of those centres. "Hand culture, apart from its value *per se*, is a means toward more perfect brain culture," and exercise by itself alone is truly educational, although this feature of it may be more fully developed and emphasized by proper systems and methods. The great trouble is that it is extremely liable to be misapplied, misunderstood, or neglected.

The aim of training should be to increase the capacity of the lungs and the breathing power, to strengthen the heart and the circulation, to invigorate the brain and nerve-centres, to improve digestion and nutrition, to make the muscles more powerful, more responsive to the will and their capacity for endurance greater, and to lessen the amount of adipose tissue. Systematic exercise also helps one to resist disease, because by it waste matters are carried off; pores, glands, and organs are kept at work and healthy and active tissues take the place of weak and sluggish ones.

Fatigue is due to lack of contractile material in the muscles to continue work, to the exhaustion of nerve-force and motor impulses from the brain, and to accumulation of waste products in the muscle.

Active exercise is that brought about by one's own movements; passive, that produced by something outside or collateral to one's own power.

It is hard to determine how much exercise any given person ought to take, as the personal equation varies so much. The average healthy man should probably do work equivalent to 150 foot-tons daily. The work of

walking on a level at the rate of three miles per hour is said to be equal to that of raising one-twentieth of the body-weight through the distance walked. According to this, a man of 150 pounds in walking one mile does work equal to 17.67 foot-tons, and his total daily physical labor should be equivalent to walking about nine miles at the above rate to get the proper amount of daily exercise. This seems like an excessive amount, but if the actual physical work of one's customary vocation be taken from this, it will probably not leave so very much for the daily health-task. The natural disinclination of many to exercise grows stronger by indulgence, and while urgent reminders are wanting and the evils arising from the neglect, abuse, or misuse of exercise are not so very immediate or apparent, the latter are still certain to result, and are not at all consistent with good and perfect health.

BATHING.

In health we make use of baths and bathing for the cleansing of the body, the stimulating of the functions of the skin, and as a tonic to the whole system. A suitable bath properly taken is exhilarating and thoroughly enjoyable. Baths are also to be employed in sickness as a means of cure, but such use of them is foreign to the present discussion.

H. C. Wood, Sr., says: "Cleanliness and the maintenance of the proper condition of the skin require the use of the bath at least twice a week. In some very delicate persons the general bath produces marked depression, but this can almost always be avoided by the use of very hot water. If the hot or warm bath be employed habitually, it should be preferably taken at night, and, unless under very exceptional circumstances, the hot bath should always be followed by cold sponging or the cold shower-bath, or by a plunge into cold water." The temperature of a cold bath may be from 40° to 75° F.; a tepid bath, 75° to 85° F.; a warm one, 85° to 100° F ; a hot one, from

100° to 110° F. A cold bath is taken not so much for its cleansing as for its tonic and stimulating effects; the others are used mainly for their cleansing properties, though if followed by the cold sponge, shower, or dip, the sense of exhilaration produced will be marked.

Cold baths taken immediately after physical exercise while the body is still warm, but after perspiration has ceased, and followed by a good rubbing and friction of the skin, dispel fatigue and give a sense of buoyancy and lightness. The shock of the first contact of the water with the skin is but momentary, and can be withstood by most persons unless there be serious organic disease; and the reaction produced certainly compensates for the primary discomfort. If the bath be taken in the open air, there is the additional benefit of a plentiful supply of fresh air for the lungs, of the physical exercise and the increased circulation induced by swimming or combating the surf, and, if in the sea, of the stimulation of the skin by the salt water. In fact, sea-bathing may be advantageous to a marked degree where the circulation and action of the skin are sluggish.

Those who are subject to organic heart disease should not indulge in sea-bathing nor in deep fresh-water bathing, since a sudden tax may be made upon the strength and the heart action be disturbed or checked. Women who are menstruating or who are in the later months of pregnancy should not take cold baths.

Baths should not be taken too soon after meals, because digestion may be lessened or entirely stopped by the blood being called from the stomach to the skin and muscles, and nausea and vomiting thus induced. "There can be no doubt that many of the cases that are called 'cramps,' and which frequently result in drowning, are due to this cause."[1] In cold baths the head should be immersed first, "to avoid increasing the blood-pressure in the brain too greatly, which might result if the body were gradually immersed from the feet upward."[2]

[1] Rohé's Text-book on Hygiene. [2] Ibid.

The following rules, issued by the English Royal Humane Society, are worth noting: "Avoid bathing within two hours after a meal, or when exhausted by fatigue, or when the body is cooling after perspiration. Avoid bathing altogether in the open air, if, after having been a short time in the water, there is a sense of chilliness, with numbness of the hands and feet; but bathe when the body is warm, provided no time is lost in getting into the water. Avoid chilling the body by sitting or standing undressed on the banks or in boats after having been in the water. Avoid remaining too long in the water, but leave the water immediately if there is the slightest feeling of chilliness. The vigorous and strong may bathe early in the morning on an empty stomach; the young and those who are weak had better bathe two or three hours after breakfast. Those who are subject to giddiness or fainting, or who suffer from palpitation or other sense of discomfort of the heart, should not bathe (out-of-doors) without first consulting their physician."[1]

After any kind of a bath the body should be thoroughly dried, not only to restore and accelerate the circulation of the skin by the friction and to prevent cooling by the evaporation of the water, but also to prevent chafing and eczematous eruptions where the skin is subject to the friction of clothing. Warm or hot baths should not be taken if the person is to be exposed to the cold within several hours, and the same rule applies to Turkish, Russian, or vapor baths; so the former had best be taken in the evening, and the latter should not be taken away from home, especially in cold weather, unless the bather rests for a time after the bath, and then wraps up well before going into the open air.

In all warm baths in health the principal object is to secure the cleansing effects, and to be effective their use must be systematic. The pores of the skin are self-cleansing only to a certain degree, and the free use of warm water is most beneficial in removing dry epithelium,

[1] See also Sea Air and Sea Bathing, by John H. Packard.

sweat, dirt, and grease. If the pores of the skin are obstructed, there are not only irritation and eruptions of the skin produced, but more work is thrown upon the kidneys, and these, if unsound, will break down the quicker. Soft water is to be preferred for ordinary bathing and washing, because it often prevents or lessens cutaneous irritation and because it saves soap.

Public baths have become a marked feature in the scheme of municipal sanitation of a number of cities, and are of benefit not only directly, but as a means of incul-

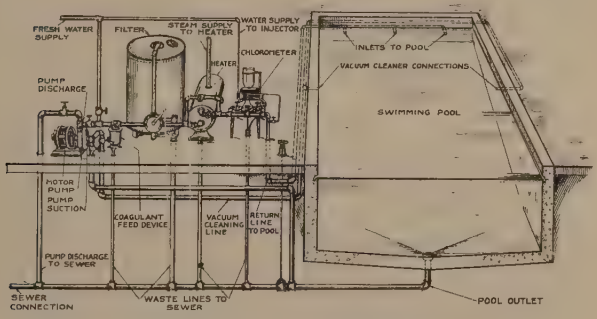


FIG. 87.—Typical installation of chlorinating apparatus for swimming pool with a recirculating system.
(Courtesy of Wallace and Tiernan.)

cating a habit of cleanliness in those who use them. Where possible, separate baths should be provided for the two sexes, and all should be at all times under competent and strict supervision. There is some danger, however, of the spread of infection, especially of skin diseases, in the use of swimming pools, or of individual bath-tubs, and shower booths should always be provided in preference to the latter. For the same reason the water in swimming pools should be frequently changed, and it is also well to attempt to render it free of infective organisms by the use of ultra-violet rays or by the addition of small quanti-

ties of certain chemicals, such as chlorine, chlorinated lime or copper sulphate.

A Turkish bath consists: (1) Of a dry, hot-air bath at a temperature of from 120° to 170° F., or even higher, for from ten to thirty minutes, which causes in most persons profuse perspiration with no sense of discomfort, but rather a pleasant sensation. After this come: (2) A hot shower-bath to wash off the sweat. (3) Shampooing, massage, and scrubbing to remove thoroughly all dirt, loose epithelium, and perspiration from the skin. These take place in moist air at from 100° to 110° F. (4) A warm shower-bath gradually changing to a cold one, and then a thorough drying of the body and a rest for a quarter- or half-hour. A Russian bath differs from this only in that moist air at 150° F. or under is used instead of dry air for the first bath.

It has been said "that a person ought never stay in either the hot-air or steam-room if in anywise oppressed, or to use very cold water afterward if one feels any shrinking from it." Nor should one who is very corpulent or who has organic heart disease take a Turkish or Russian bath without the advice of a physician. But for healthy persons they are quite pleasant and in most cases beneficial, provided they are not taken too often and that one does not indulge in them too long at a time.

The terms sun-baths, mud-baths, sand-baths, and pine-needle baths are self-explanatory. These are used in treating certain diseases, and are supposed to be especially beneficial in rheumatic affections.

SOCIAL HYGIENE.

By rather general agreement the term Social Hygiene has been applied to the consideration of the relations which the study of questions pertaining to sex may have to personal and public health. Consequently, it rightly has a place in this chapter and, because of the importance it has acquired as one of the serious influences for the

betterment of humanity both physically and morally, it cannot be ignored. "The most important act of a living thing is the reproduction of itself. With its death all its interests stop and nothing matters. With its reproduction its interests continue and give things their meaning. The continuation of life (for humans) depends upon the renewing of it every few years. And sex health largely determines the quality of life which is passed on."[1]

Until comparatively recently there was not only much restraint as to public discussion of the subject, but also great uncertainty as to what should be taught or done. It is now realized that the common welfare demands that the individual be as fully informed as possible and that the instruction of the young is of paramount interest. It is also the general consensus of opinion at present that this instruction should be given to children by their parents, supplemented by judicious teachers in the schools. The trouble heretofore has been that few parents or teachers were sufficiently well informed or discreet enough to be able to do this satisfactorily, but that objection is largely disappearing because of the earnest interest given to the duty by those concerned. "As a link in the chain of the race, the boy and the girl are of sufficient importance to justify the use of any terms which are necessary to give them the information about themselves that they need in order to understand themselves and to solve their sex problems wisely. It is the duty of parents, teachers and physicians to give them this information early enough to make sure that they get it from intelligent, clean and serious people rather than from ignorant, lewd and frivolous ones, as they often do. As soon as the child manifests curiosity about such matters he should be told the simple truth, plainly and honestly."[1]

There should also be careful oversight and guidance as to habits, and because of the increased stress upon the organism during the pubertal development, there should

[1] North Carolina Health Bulletin, January, 1926.

be watchful care to avoid undue physical or mental loads throughout this period. Disasters that do not manifest themselves until years later often have their beginnings at this time. This also is the time to inculcate in the boy and girl high ideals of the coming manhood and womanhood, and to have them appreciate the importance of maintaining sex-health. It is an accepted fact to-day that the sex glands not only produce the germ cells for the origin of the next generation but also internal secretions that are of the highest importance in determining and developing the physical character and integrity of the individual, and so the adolescent should be made to feel the high duty involved in conserving this function and in not jeopardizing the future by injudicious habits or reckless acts, no matter how enticing present temptations may be.

Boys especially should be taught that there is no warrant for a double standard of conduct for the two sexes, and that it is a good rule that whatever would not be right and proper for their mothers, their sisters or the girls they hope to marry is not right or justifiable for them. Also that, especially throughout adolescence, sexual continence is not only consistent with but highly conducive to good health and manly vigor. They should also be made to realize that if they are normally constituted they will inevitably desire to marry and to have homes and families, and that the future health and happiness of their wives and children may be determined and should not be jeopardized by their habits and conduct prior to attaining manhood, and that no pleasure or gratification of the present that is likely to bring deep and lasting regret to them and irremediable harm to others, especially to those they love, can ever be warranted or worth while.

Children of both sexes may acquire the habit of masturbation quite early and it may persist as a habit for a long time, although the self-respecting boy or girl of resolute character usually ceases to indulge in it as soon as he or she appreciates its harmful nature and influence. While it

must be admitted that many of the evils that were formerly believed and taught as consequences of the practice of this habit, such as mental breakdown, insanity, etc., can no longer be sustained even as possibilities, it can be said that for adolescents especially the habit is detrimental and vicious, harmful to self-respect, and should be overcome by moral suasion, supervision or any other available and practical means.

The so-called venereal diseases are not always due to vicious conduct but may be acquired innocently, not only by wives and children of infected husbands and fathers, but accidental contacts and the use of contaminated articles, such as common drinking glasses, towels, dental instruments, etc. While it is impossible to determine the exact incidence or even the probable prevalence of these diseases because of the veil of secrecy that is thrown about them everywhere, they are rightly looked upon as one of the greatest menaces to personal and public health and a vigorous campaign is being carried on against them not only by the medical profession in general, but by the United States Public Health Service and the health authorities of practically all the states and larger municipalities. Known cases are more carefully treated and supervised until cured than heretofore and in some states quarantine is enforced against those that insist on endangering others or who are unamenable to treatment, just as in the case of other infectious maladies. Because of the tremendous damage they do, both to individuals and in the aggregate, every one should do all in his power to lessen their incidence and should look upon them as public enemies that are not to be kept under cover but brought into the open and destroyed.

While it cannot be denied that many if not most of these diseases are now cured by careful and long-continued treatment, it should be known that many are not cured, even though all noticeable symptoms have disappeared and both the patient and his physician believe he is well. It is such cases that recur perhaps years later to plague

their victims or, what is worse, that carry the infecting germs and transmit them to the innocent. We cannot believe that the many cases of inherited syphilis transmitted to offspring or of children blinded and wives with bodies and lives ruined by gonorrheal infection were all caused by reckless and heartless husbands who knew that they were in a condition to convey the evil. In fact, every physician knows to the contrary, and the knowledge makes him redouble his efforts for a cure. Unfortunately, too, one attack of either of the principal diseases of this group does not, as in the case of many other infections, safeguard the patient against subsequent attacks, and, moreover, the fact that a patient has once been cured of his primary case of either disease gives no guarantee that he will be cured of the second or subsequent ones. Nor does either of the diseases protect against the other. The worst of it is that the knowledge and the harm may come long years after when the individual has assured himself that he is safe and has banked his highest hopes and prospects upon such assurance.

It is not the part of this work to preach morals, but as a matter of personal safety and public welfare every one should know that sexual relations with any person of either sex who is promiscuous in such relations are likely to be followed by infection with one or the other of the diseases in question. No matter what official regulations may be presumably enforced or what precautions may be taken, the danger is there and no one should minimize the danger and risk. It is for these reasons that so much effort to eliminate commercialized prostitution has been made in this country in recent years, and it is interesting to note that, according to the President of the American Social Hygiene Association, "the ten-year period from 1910 to 1920 saw the abolition of more than 200 red-light districts, and there are but few communities which continue even to tolerate open-vice sections. There still are a number of persons in this country who believe that segregation and medical regulation of prostitution is the best method

for dealing with it, but so strong a preponderance of public opinion now demands the repression of prostitution that the latter may be considered the settled policy of the United States."[1]

That the incidence of venereal diseases among soldiers, and presumably among others, may be markedly controlled by the combined influence of well-ordered physical exercise, personal education, agreeable recreation, wholesome entertainment, prophylaxis and effective disciplinary measures is demonstrated by the remarkable record of the American Army throughout the recent war, and if this can be done in the Army in time of war, certainly much may be done at home in time of peace by the proper and wise use of these and similar methods. At any rate, the interests involved in the maintenance of the public health and welfare are so great that they warrant every sensible effort that can be made to secure the desired results.

CLOTHING.

There is scarcely anything that can be said on this subject with which almost every one of ordinary intelligence is not in some respects conversant. According to Poore, the main objects to be sought in clothing the body are: "(1) To maintain the temperature and, by preventing the loss of animal heat, to diminish to some extent the demands for food. (2) To allow the chief heat-regulating mechanism—*i. e.*, the evaporation from the skin—to proceed with as little hindrance as possible. (3) To allow all muscular acts the greatest possible freedom, and to avoid the compression of the body in so far as may be possible. (4) To protect the body from heat, cold, wind, and rain. (5) To disguise as little as may be the natural beauties of the human figure."[2]

The substances from which articles of clothing are usually manufactured are wool, silk, cotton, linen, leather,

[1] Journal of Social Hygiene, December, 1925, p. 517.
[2] Stevenson and Murphy, Treatise on Hygiene.

and furs, although almost everything that can possibly be fashioned to suit the needs or fancies of the wearer is or has been utilized for the purpose. Goods of all manner and kind are woven from the first four substances mentioned, either singly or in combination one with another, and felts are made from wool, hair, or fur, these latter being made, not by weaving, but by an interlacing and matting together of the fibres by pressure and rubbing.

Wool.—In a general sense wool is probably the most valuable of clothing materials, since in a variable climate or where there are sudden changes of temperature it is the safest for the wearer to use. While, taking fibre for fibre, it probably does not vary so much from linen or cotton as a heat-conductor as is generally believed; it is usually woven in such a way as to entangle large quantities of air in its meshes, thus preventing either sudden lowering or raising of the body-temperature, since dry air is an especially good non-conductor of heat. Moreover, wool is very hygroscopic, readily taking up water and perspiration and giving them off slowly, thus reducing the cooling by evaporation to a minimum and regulating the heat-dissipation of the body. All who are subject to rheumatism or to such disturbances of health as to render them susceptible to sudden temperature-changes should wear woollen garments next the skin the year round, varying the thickness and weight, of course, to suit the season; and children and others subject to digestive disturbances will usually be greatly benefited by the constant use of a woollen (or, in case that is too heavy, a silken) band about the abdomen.

As it is ordinarily woven, some persons cannot tolerate wool next the skin on account of its irritating properties. These latter are obviated, however, if the undergarments be made of pure wool woven by methods similar to that introduced by Jaeger, or of a mixture of wool or cotton, or by wearing a garment of linen or cotton net next the skin and underneath the woollen underclothing. The Jaeger method, by the way, is said to provide for the

escape of moisture from the material and for the free permeation of air through its interstices.

Silk.—Silk is an excellent non-conductor of heat, and is almost as hygroscopic as wool, so that it is suitable material from which to make warm clothing. Its great natural beauty and the facility with which it takes coloring matter also make it desirable from an esthetic stand-point, while its great disadvantage is its high cost. For those who cannot wear wool next the skin and to whom cost is no objection, silk is an excellent material for undergarments.

Cotton.—Of all the fibres, cotton is probably the most generally used for clothing. It is not so hygroscopic by far as wool, but it is hard and durable, and is, above all, cheap, so that it furnishes the bulk of the clothing for the masses. If smoothly woven and of a light color, it makes extremely cool garments for warm climates or seasons. On the other hand, if warm clothes are desired, the cotton must be woven so as to have large air-spaces in the fabric, thus making it resemble the ordinary woollen clothing in texture and partly in function, and should be of a dark color. Cotton should not be worn next the skin by those subject to disturbance by sudden temperature-changes, nor during exercise, unless in the latter case it is changed immediately after the exercise or additional clothing is added to the body to prevent too rapid evaporation and cooling.

Linen.—Linen is valued for its purity of color when bleached, and for its durability. It is more expensive than cotton, and its hygroscopic and heat-conducting properties are about the same as the latter. It is especially desirable for use in clothing for hot climates and for articles of dress that are easily soiled and need frequent cleansing.

Furs.—Furs provide extreme protection against the wind and cold, both on account of the impermeability of the skin and of the large quantity of air entangled in the fur itself.

Leather.—Leather is utilized for foot-coverings, etc., on account of its durability, pliability, and practical imperviousness to moisture, especially when oiled; and in cold countries and by aviators is also used for body garments on account of its resistance to the wind and the efficacy with which it keeps the body surrounded with a layer of warm air.

Rubber.—With the possible exception of rubber, which is especially useful for the protection which it gives from wind and rain, other materials from which clothing is made need not be mentioned here, because of the comparative rarity of their use and their close resemblance to those already named. The value of any material for clothing purposes, however, may be said to depend upon the slowness with which it permits the passage of heat to or from the body and the evaporation of water, the amount of air its meshes contain, its impermeability to the wind, or else its special adaptability to some particular purpose.

Certain materials are manufactured from combinations or mixtures of two or more of the four fibres first mentioned, and it sometimes becomes necessary to distinguish these one from another and to determine the proportion of each in the goods. This is done by microscopic examination, each fibre having its own peculiar characteristics, and by chemical reactions. Some of these latter are as follows: Wool and silk dissolve in hot liquor potassæ or sodæ of a specific gravity of 1050, while cotton and linen are not affected. Wool and silk are stained yellow by strong nitric or picric acid; cotton and linen are not. Sulphuric acid affects wool but little, slowly dissolves silk, and changes cotton or linen into a gelatinous substance that is colored blue by iodine. Hot concentrated zinc chloride dissolves silk, but not wool; and copper dissolved in ammonia rapidly dissolves silk and cotton, linen more slowly, but only slightly swells wool.

Cloths are often sophisticated in the process of manufacture, and their value greatly lessened thereby. Wool

is mixed with "shoddy," which is made from old and used woollen rags torn asunder and then respun with an addition of fresh wool; silk is heavily weighted with salts of tin, iron, or with other substances; and cotton and linen are stiffened and glossed with an excessive amount of starch, white earth or the like. Shoddy can be determined by the use of the microscope; the weighting of silk by chemical reactions and solutions; and over-starching, etc., of cotton and linen by washing and drying.

It will not be advisable here to go fully into consideration of the influence which the shape and style of the individual garments of ordinary use have upon health, for that would require a much longer discussion than the present space permits; but the general rule may be laid down that each article of clothing should be adapted to the peculiar needs and occupation of the wearer, and that it should in nowise interfere with the proper development, use, or physiological functions of any part of the body.

Trite and hackneyed as is the subject, the writer feels that he would be wanting in the performance of his duty if he failed to condemn the habits and fashions of dress that manifestly violate the principles of hygiene by interfering with any of the normal functions of the body. All sanitarians practically agree upon the importance of "vital capacity," as measured by the development and extent of expansion of the thorax, in determining the constitution and health of the individual. But not only may the corset or other constricting garment harm by interfering with the functions of respiration and circulation, but it may also deform and induce even more serious troubles by its displacement of the abdominal and especially of the pelvic organs, and by the grave interference with the nutrition, tone, and functions of all of these. It is a fair challenge to any woman who declares that she does not dress too tightly, to ask her to measure honestly her waist circumference and expansion both with and

without the garment in question, and to make her decision accordingly. And it is certainly false doctrine to teach that it is really necessary that the normal human body should have artificial support. The natural muscles kept in proper training, tone, and action are all sufficient to give the most perfect and most beautiful human form. The large number of women who have almost entirely abandoned the use of the corset and their saner views regarding the size of the normal waist line is an added evidence of the progress of hygienic education.

Another matter of serious moment is the harmful influence of ill-fitting and improper shoes upon the structure and function of the foot. This was demonstrated, so far as men are concerned, by the unduly large number of men rejected for military service in the recent war because of defective feet, as well as by the remarkable improvement and benefit experienced by many others after wearing for a short time the army shoe made upon the normal last. How much more serious is the effect of the abnormal styles and high heels of women's shoes can be readily demonstrated and should be appreciated by thoughtful students of hygiene.

When exposed to the sun's rays or to other sources of radiant and incandescent heat, fabrics absorb heat irrespective of the constituent materials, but in the following order as regards color: white, light yellow, dark yellow, light green, Turkey red, dark green, light blue, dark blue, and black, the latter color absorbing more than, and light blue almost twice as much as, white, the material in each case being the same. In the shade the degree of absorption depends more on the material than on the color.

Lastly, it should be remembered that, as disease germs are readily conveyed from place to place and from one person to another by the clothing, and especially by that which is hygroscopic by nature, care should be taken to keep the garments in as cleanly and aseptic condition as possible, to disinfect them whenever they have been exposed to infection, and, for those who are much among

the sick or liable to infection, the use of smooth, closely woven, non-hygroscopic outer or overgarments that can be readily cleansed, such as those made of cotton or linen, is to be highly recommended.

LIGHT.

The important influence of sunlight in the development and maintenance of a healthful condition in all higher organisms, both animal and vegetable, is well known by everyone, but as yet there is only partial information as to the exact physiological methods and processes which are due to this great force. We know that, for the plants, chlorophyll is the intermediary agent which largely assists in the conversion of carbon dioxide and the storage of carbon in various compounds, and that the presence and action of this chlorophyll are largely dependent upon the light-supply; while for the animal kingdom, and especially for the human race, it is evident that the effect of sunlight is manifested more or less directly in the blood and skin, though the whole body quickly shows a marked appreciation of its presence or absence.

The subject demands further study, and it may not be out of place to indicate one or two directions in which the investigation may, perchance, be wisely pursued.

In the first place, there has doubtless been too little appreciation of the fact that sunlight in its totality has many other rays of force than those which manifest themselves alone to our sense of sight. The existence of the ultra-violet rays and the fact that these are more powerful actinically than those of the visible spectrum have been satisfactorily demonstrated, and the only question is as to what the true physiological power and influence of these invisible rays may be.

"The essential importance of ultra-violet rays in medicine has just begun to be appreciated. The action of these rays, as distinct from the visible radiations of the sun, has been known for many years, but physiologists have

only recently become fully alive to their significance in relation to the normal and pathologic conditions of man. This is all the more surprising in view of the fact that plant physiologists have laid great stress on the rôle of the invisible or 'chemical' rays of the sun in the biologic processes of the vegetable world. . . . It was not until it could be shown objectively in man and in animals, by means of the roentgen-ray and by chemical analyses of the blood, that a nutritional disturbance—rickets—came about as the result of a lack of the ultra-violet solar rays, and could in turn regularly be prevented or cured by these irradiations, that their importance in physiologic and pathologic processes was fully appreciated.

"These rays constitute less than 1 per cent. of the total solar radiations, and it is therefore all the more remarkable that they should prove to be essential to the well-being of man. The young, rapidly-growing infant thrives better when deprived of the visible rays than when deprived of the ultra-violet rays of the sun.

"It is still impossible to state what action these rays exert on physiologic processes. It has been fully established that the formation of pigment in the skin is due to the ultra-violet part of the spectrum, and it has also been shown that the invisible rays lead to an increase in the lymphocytes in the blood, an observation that is of interest in connection with their curative action in infections of the lymph glands. . . . Rickets is characterized by a disturbance in the mineral metabolism, which is manifested by an alteration in the structure of the bones and a diminution of the organic phosphorus or of the calcium of the blood. Both of these abnormal states are rectified when the infant or animal is exposed to the sunlight or to the ultra-violet radiations from an artificial source. . . . There is likewise an indirect action, a power in ultra-violet radiations to produce an antirachitic factor in plants, in vegetable oils and in leafy vegetables, endowing them with the potency to prevent rachitic changes in the bones."[1]

[1] Hess, Alfred F.: Jour. Am. Med. Assn., vol. 84, p. 1033.

It is interesting to note in regard to the last statement that cod-liver oil, which has long been known as one of the very best remedies in the treatment of rickets, has its value in this respect increased by exposure to ultra-violet radiation, and that the same seems to be true with regard to milk and other foodstuffs Bloch and Faber of

FIG. 88—Tubercular children at Pennsylvania State Tuberculosis Camp at Mt. Alto, Pa.[1]

Copenhagen believe that light and particularly ultra-violet rays have a stimulating effect on the organism which chiefly benefits those functions that are depressed, while, according to Oppenheim, "Two points appear definite; that the skin is an organ of internal secretion, affected by light, and that pigmentation is important in the utilization of light rays by the body." In his

[1] Figs. 88 and 89 by courtesy of Penna. Department of Public Health.

experience since 1910, "Actino-therapy in surgical tuberculosis and in pulmonary tuberculosis in its early stage greatly surpassed all earlier methods of treatment in efficacy. The ultra-violet rays—the 'life-rays'—are winning their deserved place in therapeutics."

Again, the destructive effect of sunlight, and of light from minor sources as well, upon the germs of disease and other low forms of life, and upon their toxic products, is now a matter of common knowledge, though many are not aware that it has been proved that this germicidal

FIG. 89.—Sun-light treatment at Pennsylvania State Tuberculosis Camp, at Mt. Alto, Pa.

action of light is directly in relation to its actinic power. Especially has it been shown that the ultra-violet rays quickly destroy the vitality of microörganisms and the toxins produced by them. Considering this, together with preceding statements, may we not surmise that hostile organisms, even in the deeper tissues, are overcome both in this way and by the improved condition of the blood due to the light, and that this hypothesis helps to explain the good results that follow the open-air treatment of many diseases and abnormal conditions? The tubercle

bacilli are especially susceptible to its influence, and every one should know that an abundance of sunlight is just as essential to the tuberculous patient as are plenty of good food, pure air, or proper clothing.

"Recent experiments on the effect of radiation on the bactericidal power of the blood indicate that exposure of the skin of animals to a source of ultra-violet radiation gives an increased bactericidal power to the blood and serum. . . . In the investigations of Hill and Colebrook the rays from a carbon-arc or a mercury-vapor lamp, as well as certain heat rays, were found to raise the bactericidal efficiency of the subject's blood, this effect being referable to improved function of the leucocytes."

It is interesting to note that "more of the ultra-violet rays, even on sunny days, come from the sky as a whole than directly from the sun; this is particularly the case when the sun is low or obscured by cloud, and is a fact of practical importance in heliotherapy."[1] However, because of the variability and uncertainty of the sunlight and other natural sources of the ultra-violet rays, much use is made of mercury-vapor and carbon-arc lamps as furnishing more definitely measurable and larger supplies of these rays for therapeutic use.

Bie, Finsen, Rollier, Hess and others have done much to develop the treatment of disease by light, whether from the sun or artificial sources, and good results are frequently obtained from such treatment, especially in the case of surgical tuberculosis and of cutaneous or superficial diseases. And although more might be said in reference to the possible and probable chemical activity of the light in and upon the metabolic processes of the animal body, as there is still the uncertainty of hypothesis and theory, it may be wiser simply to leave the foregoing statements as food for thought and incentives to further research and investigation.

The importance of an abundance of daylight in all

[1] Jour. Am. Med. Assn., vol. 84, 1498–1499.

rooms where much work is to be done should not be overlooked. Not only is it necessary for the conservation of the influences just mentioned, and as a destroyer of pathogenic organisms, but it is also more agreeable and safer for the eyesight than any form of artificial light

FIG. 90.—Heliotherapy, Sea Breeze Hospital, Sea Gate, New York, March 18, 1913. Cured case of tuberculosis of the knee. No sinus. (Hinsdale's Atmospheric Air in Relation to Tuberculosis.)

yet devised. An important aid to the illumination of dark interiors has been the introduction of panes or plates of glass with a series of ridges or prisms, which refract and diffuse throughout a room light which would otherwise illuminate it but partially or not at all. The prisms are made with various angles, and may be placed

either in the ordinary window sash or in projecting canopies, according to whether the direct light from the sky is obstructed or not. (Fig. 91.)

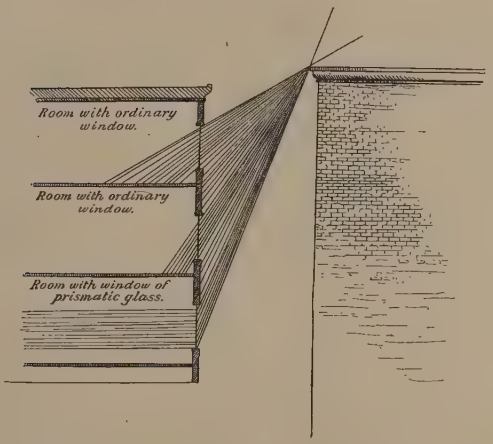


FIG. 91.—Action of prismatic glass in projecting light. (Harrington.)

The relation of artificial lighting to ventilation has been discussed. In addition to this point, the quantity of light supplied and its steadiness have an important bearing on the hygienic value of any artificial source of illumination that it may be necessary to employ.

CHAPTER XI.

SCHOOL HYGIENE.

It was remarked in the chapter on Personal Hygiene that the best time for applying the laws of hygiene is in the days of childhood and youth, for then the whole organism is plastic and yields readily to both external and internal impressions and forces.

This being so, the great influence of the factors common to school-life may be readily conceived, and inasmuch as the average child will be subject to them for a large part of from eight to ten or more years, the importance of a study of school hygiene will not be denied. It concerns the parent, the physician, and the citizen, and its investigations must consider the personal hygiene of the scholar, the conditions of his health, his habits, the amount of work done, the sanitary environment and requirements of the school-room and building, the furniture, the ventilation and heating, and the influence of all these upon the individual's state and development.

Next to the scholar himself and his parents, these matters are of special interest to the physician, for, in addition to being one who from his special training and education is often called to act upon school committees and boards of education, or as a medical inspector of schools, he has to treat many disturbances of health in the young which have their origin or cause in the harmful or insanitary conditions of school-life.

There are disorders to which all children are subject whether in school or out; but a special class are markedly influenced by school-life or work, and to these abnormal conditions we may give the term "School Pathology." Of some of these, overwork is the cause; others are set up by other factors.

Overwork, coupled with depressed vitality or other influences, may give rise in children to one or more of the following troubles: dyspepsia, headaches, nervous derangements, chorea, epilepsy, neurasthenia, backaches, menstrual disorders, and, in some cases, consumption. On the other hand, faulty arrangement of seats and desks, improper location of windows, blackboards, etc., may cause spinal and other physical deformities, defective eyesight, etc. Of the first class, even where the amount of work may not seem, or may not really be, too much for the capacity of the child, worry about rank or over an approaching examination may have a harmful effect upon a nervous temperament. This is especially so if the examinations come at the end of a spring term, when the scholars are all more or less worn-out and debilitated. The forcing process should be avoided as far as possible, and if grades are to be given at all, they should be as much as possible for the work and attendance during the term, and not so much for the actual work done at examination time.

Moreover, young children should not be kept in school for too many hours in the day, nor should school be looked upon by parents as a place to which to send children to keep them out of the way and from mischief. Edwin Chadwick has shown that a child from five to seven years can only attend to one object for about fifteen minutes; one from seven to ten, for twenty minutes; from ten to twelve, for twenty-five minutes, etc., and that the length of individual lessons and likewise the total day's work should be arranged accordingly. The very early years of school-life should be given to inculcating correct habits of attention and of morals and to training the will and powers of concentration and observation, rather than to the teaching of any special knowledge.

But apart from the physical conditions of the schoolroom and postural and other personal habits of the pupils, it is probably the work attempted outside after school hours, and not the actual work done in the school, that is most responsible for the breaking down of health,

especially in older scholars. In Cleveland, in 1881, of 186 girls in the high school, 29 per cent. of those who studied less than two hours, 70 per cent. of those studying from two to four hours, 93 per cent. of those studying from four to six hours, and 100 per cent. of those studying over six hours daily out of school, had poorer health while at school. Of these same girls, the percentages of those whose health was "very poor while at school," dividing them the same way as regards overwork, were respectively 14, 40, 66, and 100 per cent. This loss of health was attributed by the parents to stair-climbing, irregularity of meals, worry about rank and examinations, etc.; but Goodell said: "So commonly do I find ill health associated with brilliant scholarship, that one of the first questions I put to a young lady seeking my advice is, 'Did you stand high at school?' " Another writer says: "The effects of anxiety are worse than carrying heavy loads."

In fact, one of the leading educators of the country of his time suggested years ago that children should not be required to study reading, writing, or drawing before the age of ten or eleven, as these bring into action and use the close application of the finer sense organs and faculties which are not as yet fully developed; but he advises that the instruction of the earlier years of school-life should consist mainly of language lessons, history, nature studies, and such others as may be taught orally and that will at the same time develop the child's powers of attention, observation, and reasoning. There is more than a chance that such a plan of instruction would not only secure better results from the teacher's point of view, but that it would also be safer for the scholar's physical organism.

While a child is at school its mind should not be wearied by outside tasks, as music or painting lessons, nor the body weakened by social dissipations, late hours, and indigestible food. Girls are more susceptible to disturbances of health, and are more subject to them, because they are more willing to undertake extra or double work

than boys, and because they are more ambitious and worry more about rank. In all children the obtaining of good health and a sound constitution is of the first importance. Youth is the time for gaining health, not for losing it; for building up sound bodies and constitutions, not for breaking them down, and school-life should always have the former as one of its greatest ends. Of what use is all the learning one may gain before the age of eighteen, if there be no strength to use it afterward in the battle of life?

School-life is sometimes responsible for dyspepsia by interfering with the regularity of meals, the children missing the mid-day meal and having to depend upon a meagre lunch, often of sweets and indigestible food. This is especially important when the rest of the family dine at noon, and there is only a light meal served in the evening. Again, many habitually lose their breakfast through fear of being late, or else bolt the food without masticating it and gulp down hot coffee or tea before starting on a run for school. But often the loss of appetite is due simply to lack of fresh air and proper exercise, or else to the nervous condition of the child, which is sometimes such as to interfere with almost all of the body functions. Such dyspepsias are to be treated by attention to the foregoing points rather than by medicine.

Headache is a common disturbance among school-children, and may be due to any one of several causes, among which are overwork—producing irritability and disturbances of cerebral circulation—indigestion, bad air, eye-strain, etc. The eyes should always be examined when headaches are persistent, and any defects corrected by proper glasses. Associated with the headaches, frequent bleeding from the nose may occur and should not be overlooked, as it may indicate circulatory disturbance.

"Eye-strain is a particular evil of civilization, and makes its first appearance in school when the scholar tries to accommodate the eye to the short range which reading requires, but for which the eye mechanism is not well

adapted by nature." "In New York City 29.5 per cent. of 79,069 children examined suffered from defective vision. In London 26 per cent. of 20,000 children examined by eight ophthalmologists had defective vision, and of this number 12.5 per cent. suffered from vision of one-half or less. In Philadelphia 34 per cent. of 1156 children had defective vision, and of this number 6 per cent. had vision of one-half or less. A small proportion of this number only is fitted with glasses. The rest suffer from real eye-strain."[1]

One of the most common symptoms of nervous derangement is sleeplessness or restless sleep, and this condition should give warning that something is wrong. Folsom says: "I doubt whether there is an exaggerated prevalence of manifest or well-marked diseases of the nervous system among school-children. If due to the school-drill, my impression is that they come for the most part later in life, after the children have left school, and because of constitutions weakened during school years, instead of strengthened as they should be." Children subject to chorea or epilepsy should not attend school, not only for their own sake, but also for that of the other children, who may be unduly affected by their nervous manifestations. Such children should be educated quietly and cautiously, with proper treatment and plenty of out-door life. Neurasthenia or general break-down may occur, usually from overwork, and especially among young women. It may come on unexpectedly after the examinations at the end of the term, when the strain and excitement are removed.

Menstrual disorders are also apt to occur among girls that are being overworked mentally, and we ought to remember that the system is undergoing a heavy strain at the time this function is developing. Also, for certain young women rest from customary work is necessary at the time of the periodical recurrence, and excuses for absence at this time ought to be freely granted. It has

[1] Report on National Vitality, Fisher, pp. 8, 74, and 75.

been well said that "girls get through as much work as boys, working in their own way."

The development of consumption may be due to the school-life, though it is hard to say how frequently this is the case. Bad air and overwork are both important factors in its production, and if these are forced on underfed or predisposed children the disease may be provoked.

Only recently have we realized that a large proportion of the cases of tubercular infection occur in early life. The greatest mortality from this disease is in the first two years, after which there is a quiescent period for about ten years. Then, at the age of twelve years in girls and approximately sixteen in boys there begins a new and marked increase in the mortality-rate which apparently must be due to the lighting up of the disease from latent foci in the body rather than to a new infection from without. The notable recrudescence of the disease at these ages is most reasonably to be attributed to the stresses incident to pubertal development and should warn us that added burdens at this time, whether of the school or home, are positively inadvisable.[1] "In a consumptive family the steadfast rule should be that the mind be wholly subservient to the body's welfare."

The main cause of spinal and other deformities and defective eyesight is apt to be found in faulty construction of seats and desks, improper location of windows, etc., though excessive work or strain may maintain a low vitality and act as a predisposing condition. The latter point is shown by the fact that spinal curvatures are more prevalent in those especially prone to weakness of the muscles, as women and girls. But no desk or seat will remove original weakness of muscle as the one important predisposing condition, and children cannot be made strong by supports. "Spinal curvature is not only a product of low vitality, but does harm by permanently fixing vitality at a low standard."

[1] See Hess: Tuberculosis in Children, Jour. Am. Med. Assn., January 11, 1919, pp. 83 88.

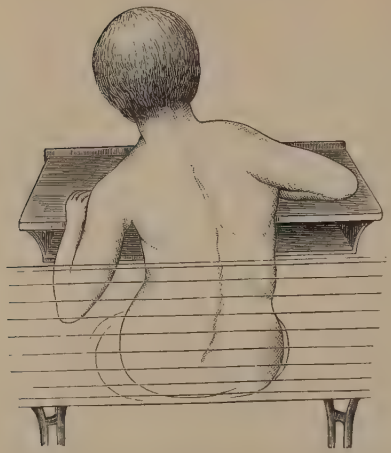


Fig 92.—Position assumed in writing with the desk too high. (Pyle.)

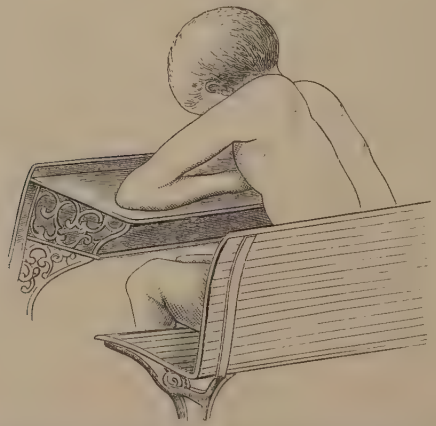


Fig. 93.—Position assumed in writing with the desk too low. (Pyle.)

Improperly arranged seats and desks not only often cause spinal deformities, but also help to develop defective eyesight by causing the scholar to hold the book too near the eyes and by making him bend his head so that the circulation of blood is impeded and ocular congestion favored. However, no seat can be devised in which a child will maintain a correct or "normal" position for any but a short time, as this is an impossibility for young children; but the aim should be to furnish a seat in which one will naturally assume the correct position after having temporarily taken any other. "Movement is a child's way of resting; rest is a kind of work, to be taught by degrees." Seats should have backs to prevent fatigue, but a comfortable back gives support to the lower part of the spine rather than to the shoulders and upper part of the spine. Many foreign authorities advise seats with backs only high enough to support the lower part of the spine, and low enough for the scholar to rest his elbows upon them while studying.

The following points, suggested by Lincoln, are worth noting: "(1) The chair is often too high for young scholars. The most convenient plan may be to provide foot-stools. (2) The seat from back to front ought to be long enough to support the whole thigh. A more or less spoon-shaped hollow in the seat is commonly thought desirable. The curve of many settees is such as to produce pain at the point where the tuberosities of the ischium rest on the wood; the support is there not wide enough. (3) Seats must have backs. The straight, upright back reaching to the shoulders is bad; a straight back, slightly tilted, is not bad. American seats are commonly curved, with curved backs. (4) The edge of the desk should come up to, or overlap, the edge of the seat. The recognition of this fact is a recent discovery. (5) Most of our best desks are too high relatively to the seat, doubtless to prevent the pupil from stooping. Something is gained in convenience of reading by this plan, but it interferes with correct positions in writing. The elbows, hanging freely,

should be only just below the level of the lid." For near-sighted children the higher desk may be a necessity in writing; if the desk is made low, a portable writing-stand may be placed on top of it when necessary.

Windows on only one side of a large school-room may not give sufficient light for the desks most remote from them. Consequently there should be windows on two sides, preferably adjoining ones, of large school-rooms. The windows should be at the back and to the left of the scholar, thus giving the best light upon the desk for either reading or writing. They should not be placed in front of the scholars, as the continuous glare is very trying and injurious to the eyes. They should extend almost to the ceiling and have square tops, to admit as much light as possible. In some cases refraction prisms (Fig 91) may be used to advantage. Blackboards should have a dead-black surface, not a glossy one, and should be on the sides of the room on which there are no windows. Walls should be of a neutral tint, not glaringly white.

In some cases considerable additional diffusion of light may be secured by installing a series of light-colored curtains corresponding in color to the walls of the room and that may be drawn to cover the blackboards when the latter are not in use.

CONSTRUCTION OF SCHOOL-HOUSES.

The principles already given as to ventilation, heating, water-supply, etc., apply here as elsewhere. Until comparatively recently it was considered essential that from 1800 to 2500 cubic feet of fresh air per hour should be supplied for each pupil because of the belief that it was necessary continually to change the composition of the air by removing carbonic acid gas, "crowd-poison," etc.

The newer ideas regarding ventilation have changed this and, as was quoted in the chapter on Ventilation, the American Public Health Association at its annual meeting

in October, 1925, authorized the statement that "Hundreds of thousands of dollars are wasted every year on this continent in the installation and operation of systems of school ventilation which are not only not beneficial but positively harmful to the health of school children. In the light of current knowledge, the supply of as large an air volume in schools as 30 cubic feet per minute per capita is necessarily accompanied with dangerous overheating of the school-room in order to avoid resulting draughts," and the Association adopted the following resolution: "That the system of ventilating school-rooms by fresh untreated out-door air, admitted by the windows, with gravity exhaust ducts for removing vitiated air from near the ceiling, is the most generally satisfactory method of school ventilation;" also "That state laws and city regulations interfering with such scientific and economical methods of school ventilation should be repealed in the interests of the public health."

Whether we are ready as yet to acquiesce in all of this or not, it is certain that there is no necessity of introducing such enormous quantities of air into school-rooms and that much of the expense of heating this in cold weather could be saved or applied to better purposes. Doubtless it will be possible to retain the present heating apparatus of many schools and by cutting down the volume of air supplied to that sufficient to maintain a moderate circulation of proper temperature and humidity, to warm and ventilate the rooms at greatly reduced cost. But new installations should be planned and based on the newer ideas and every advantage taken of the latter to give the schools the most healthful and satisfactory ventilation and heating systems possible. Country schools may be heated by stoves surrounded by sheet-iron drums, and ventilated with fresh air from without brought in near the bottom of the stove. (See Figs. 28 and 31.) Passing up between the stove and drum the air is warmed and gives good ventilation without chilling or draught. As great a length as possible of stove-pipe

should be exposed in order to get the full benefit of the heat from it.

The Smead system of ventilation and heating has been used with satisfaction in many schools throughout the country. In this, the air being warmed and brought into the school-rooms at a level a few feet above the floor, circulates through them and is finally withdrawn through registers at the floor level, whence it is carried underneath the floors to large outlet shafts in which a draught is constantly maintained. In this way thorough diffusion

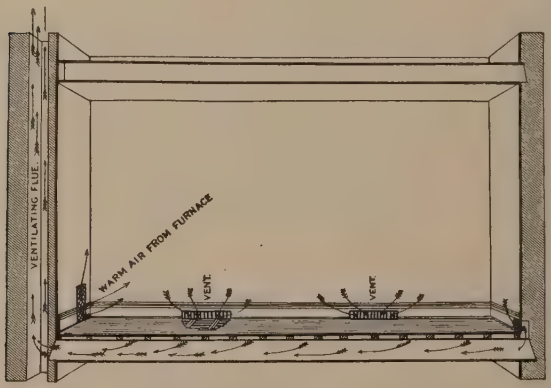


FIG. 94.—Illustrating the Smead system of ventilation.

and changing of the air in the school-rooms are secured, and, moreover, the floors are kept warm by the heat from the air which is passing beneath them and which would otherwise be wasted. (Fig. 94.)

The relative size of the school-room is of importance. Each pupil should have about twenty square feet of floor space, and as there should not be over forty pupils to the room, the total area of the room should approximate 800 square feet. The length of the room will depend not only upon the distance both teachers and pupils can be

heard distinctly, but at which the scholars can see the blackboards, charts, etc., distinctly, and school management is undoubtedly easier in a room that is not too long. Experience shows that ordinary blackboard writing is visible at twenty-nine feet, so the maximum length of the room will be about thirty-two feet, this allowing for an aisle of sufficient width at the rear of the room.

With the area of the room already determined as indicated above, this length necessitates a complementary width of twenty-five feet, a dimension that is also in a measure governed by the principle that the width of the school-room should not be much more than twice the height of the top of the windows, which in turn, should extend almost to the ceiling. And as it is agreed that the ceilings for rooms of this size and purpose should be about 12 or 13 feet high, the width mentioned is a correct one.

Ample cloak-rooms should be provided for every school; they should be warm and well ventilated in order to secure the rapid drying of the garments in wet weather, but they should not communicate directly with the school-rooms themselves, if it can be avoided. Provision should also be made for readily disinfecting them, and, in fact, the whole school building at intervals and whenever necessary.

In 1897 at Newcastle-upon-Tyne, "the experiment was tried of closing each school, where scholars were being taken ill, for a few hours only, long enough to allow of thorough purification and the *sprinkling of the floors of class-rooms with disinfectants*. This disinfection so far as measles was concerned, was followed by the extinction of the disease in question."[1]

The school-house should be on dry and well-drained soil, as dampness is not only depressing to all constitutions, but is also an important factor in the causation of phthisis and strumous diseases. There should not be too much shade about, and as many rooms as possible should have

[1] American Year-book of Medicine for 1900, pp. 543 and 544.

sunny exposures. If the sunlight is annoying during the session, it may be excluded by inside blinds or shutters, but we must not lose sight of its helpful influence in the destruction of bacteria and purification of organic matters.

Where sunlight is scanty or it is difficult to illuminate the school-rooms, it may be advantageous to furnish one or more of the windows with some form of the diffusing and refracting prisms already described (page 374), thus giving an abundance of light where there was formerly a deficiency, and materially lessening the eye-strain of the scholars.

Basements of school-houses should be well lighted and dry, and should be kept scrupulously clean that offensive and noxious gases may not be drawn into the rooms above. If properly arranged and cared for, they may be used as play-rooms in stormy weather when it would be unwise to send the scholars out-of-doors.

Open-air Schools.—A striking innovation of recent years is the open- or fresh-air school, the first being established in Germany in 1904, and in this country, in Providence, R. I., in 1908. Since then others have been opened in many American cities, and "there is but one reason against the very extensive adoption of the open-air school —its expense. The cost per capita (about $140 per annum) is four or five times that of the per capita cost in the regular school."[1]

As Cornell further says: "The fresh-air school is really a sanatorium. It provides not only free air, but also nourishing food, enforced rest, warm clothing, individual teaching, sympathetic care, and medical attention which corrects eye-strain, adenoids, decayed teeth, and anemia. Naturally, the health benefits of the open-air schools are due to other causes as well as the fresh air."

Nevertheless, the results obtained are most striking and have served to increase the enthusiasm of the advocates of these schools, for it must be remembered that the pupils in them have been selected because they were

[1] Cornell's Health and Medical Inspection of School Children, p. 115.

PLATE I

An Open-air School under the Direction of the Phipps Institute, Philadelphia.

Located on the roof of the institution. (Newmayer.)

poorly nourished, had a marked tubercular tendency, or were even in active stages of tuberculosis. The gain in weight, strength and health, increase in mental activity and progress in school work are marked, and all serve to

FIG. 95.—Type of sanitary drinking fountain installed in schools by placing bubbling-cups on old fixtures. (Newmayer.)

justify these schools and the increased cost of maintaining them.

The water-supply should be free from impurities and as good as can be had. In the country, if from a neighboring farm-house spring or well, it may be contaminated by

leakage from cesspools and barnyards. Or the school water may be taken from a neighboring spring or stream which is receiving contamination from the school-house cesspool or other sources. For this reason, teachers should be taught the tests for chlorides and ammonia and the reason for making them, and should make these tests frequently. If cause for suspicion arises, the use of the water should be stopped at once.

Water-closets and urinals, where in use, should be kept clean by a competent janitor, and the principal or head-teacher should see that this is done. In the country, the pail or earth-closet system should be substituted for the usual privy-vault or cesspool, and it should be the duty of some one apart from the teacher, regularly appointed and paid by the school directors of the district, to see that removals are made at proper intervals; the teacher should maintain supervision over the daily condition of affairs. If possible, the out-houses should be connected with the school-house by covered ways, that the children may not be exposed in inclement weather; but these ways should be open or else constantly ventilated by open windows on either side. Cesspools, if unavoidable, should be at least fifty feet distant, and should drain away from the school-house.

Though approving the Smead system of warming and ventilation for school-rooms, the writer cannot say that he approves that modification of it wherein the foul air from the building is carried over the fecal excreta of the inmates before being discharged into the outlet shafts and carried to the outer air. Though the method rapidly desiccates the excreta and renders it inoffensive to the senses, there is danger of the dissemination of disease germs as well as a departure from sanitary principles in the method.

Ample provision must be made for the rapid escape and for the safety of scholars and teachers in case of fire or panic. Fire-drills should be regularly practised in all schools of two stories or more, and presence of mind inculcated, that emergencies may be met with safety.

PLATE II

Outdoor School on Roof of College Settlement in Philadelphia.

Food, nursing and medical direction by the Phipps Institute. Teacher supplied by the Board of Education. (Newmayer.)

PLATE' III

Open-air School for Tuberculous Children.

Ferry Boat "Southfield," Bellevue Hospital. (Hinsdale.)

The comfort of the child should not be forgotten in the construction of the school-house, though preservation of health is the main aim.

The importance of ample and properly equipped school- and other playgrounds for children should also be emphasized. Not only does active natural play in suitable surroundings do far more for the physical welfare of the body and the invigoration of the mind than formal gymnastics, even though it be admitted that the latter have a place in education, but the former also aids in establishing a better social and moral status among the children by affording natural outlets for exuberant energy, developing self-restraint and consideration of others, keeping the boys off city streets, and preventing thoughtless or malicious mischief. Such playgrounds should, wherever possible, have competent supervisors in attendance to advise, encourage, and instruct those who make use of them, as well as to prevent disorder or abuse of privileges.

MEDICAL INSPECTION OF SCHOOLS.

As certain diseases are contagious, it is necessary that school authorities have the right to forbid the attendance of such persons as have been exposed to infection until all danger of transmitting the disease to others is passed. This power is usually, however, exerted only in the case of those diseases most dangerous to life and health, though the stringency of the regulations varies at different places. Smallpox, scarlet fever, diphtheria, measles, and even whooping-cough should always be quarantined, and it would be better to keep children who are afflicted with minor diseases of this class out of school till all danger of infection is over, as it is only by rigid measures like this that we may finally be able to eradicate those maladies. Considerable evidence now supports the view that there is a marked decrease in the prevalence of both scarlet fever and diphtheria during the summer holidays and an increase in the fall and winter due

to school attendance. But Niven, of Manchester, England, thinks that "the extreme measure of closing a school for scarlet fever is rarely called for, and is not so likely to be effectual as in the case of measles."[1]

Local boards of health should make and enforce rules looking to the prevention of the spread of the graver contagious diseases, and should, when necessary, close school-buildings till all danger is past. Lincoln gives the following as a system of general regulations: "(1) Persons affected with diphtheria, measles, scarlet fever, or smallpox (varioloid) must be excluded from the schools until official permission is given by the board of health for their readmission. (2) Persons living in a family or house where such a case occurs are also excluded until similar permission is given. (3) This permission is not to be given until sufficient time has elapsed since the occurrence of the last case to insure safety, nor until the premises have been disinfected under the direction of the board of health. (4) If a child suffering from one of the above diseases attends school, the premises of the school must be disinfected under the direction of the board of health before they are used again. (5) Physicians, teachers, school-officers, and school-children knowing of such cases of disease should at once report them to the board of health. (6) The board should also notify the school authorities of all such cases. (7) Notice must be sent to the family by the school authorities, acting conjointly with the board of health."

In some cities a card catalogue is kept of all the pupils in the public schools, each card representing a single pupil and giving full information concerning his or her home, parents, brothers and sisters, and where the same are employed, or are attending school. In case of the absence of any pupil for three days or more, the city board of health must be notified by the school authorities and the scholar is not permitted to return to school until the health officers are satisfied that there is no danger of

[1] See Public Health, February, June, and September, 1899; also American Year-book of Medicine for 1900, p. 538.

infection and have so notified those in charge of the school. Competent and wide-awake truant officers are also frequently able to give early notice of the occurrence of infectious disease in the homes of school children so that prompt precautions against its spread may be instituted.

The following table of the periods of incubation of the respective diseases is based on an experience of over twenty-eight years at the Rugby School, England, by Clement Dukes.[1]

AN ANALYSIS OF THE PERIODS OF INCUBATION.

Name of disease.	Shortest period of incubation (days).	Longest period of incubation (days).	The largest number occur on the following days.	The majority of the cases arise between the following days.	Percentage referring to previous column, *e. g.*, 59 per ct. occur between the second and fourth days.
Scarlet fever .	1	9	Second and fourth	Second and fourth	10 out of 17 = 59 per cent.
Chicken-pox .	13	19	Fifteenth	Fourteenth and seventeenth	24 out of 36 = 66 per cent.
Mumps . .	14	25	Nineteenth	Seventeenth and twentieth	50 out of 69 = 72.46 per ct.
Rose-rash .	12	22	Sixteenth	Fourteenth and seventeenth	31 out of 40 = 77.5 per cent.
Measles . .	8	14	Eleventh	Ninth and twelfth	18 out of 24 = 75 per cent.

Another authority gives the following:

TABLE OF THE ERUPTIVE FEVERS.

Name.	Incubation.	Day of rash.	Duration of eruption.	Duration of disease.
Chicken-pox .	4 to 14 days	Second or third	4 to 8 days	1 to 2 weeks
Erysipelas .	1 to 5 days	First to third	4 to 8 days	1 to 3 weeks
Measles . .	10 to 12 days	Fourth	3 to 5 days	10 to 14 days
Rötheln . .	7 to 17 days	First or second	1 to 3 days	4 to 7 days
Scarlatina[2] .	1 to 21 days	Second	4 to 10 days	2 to 3 weeks
Smallpox .	8 to 14 days	Third or fourth	16 to 25 days	3 to 5 weeks
Typhoid fever	10 to 21 days	Seventh to fourteenth		3 to 4 weeks

[1] Lancet, April 29, 1899.

[2] In regard to the discrepancy in the above tables respecting the incubation of scarlet fever (from one to twenty-one days), the writer believes the shorter period to be more nearly correct; also that the incubation period of measles is frequently less than ten days, as is occasionally that of typhoid fever. Relapses may extend the duration of typhoid fever to much more than four weeks.

Children having had one of the above-named diseases may return to school with safety after the following periods, provided there has been a thorough disinfection of their homes and clothing: "Scarlet fever, six weeks from the date of rash, provided desquamation and cough have ceased. Smallpox and chicken-pox, when every scab has fallen. Whooping-cough, after six weeks from commencement of whooping, providing the characteristic spasmodic cough and whooping have ceased, or earlier if all cough has passed away. Diphtheria, not less than three weeks, if convalescence is completed; there being no longer any form of sore throat nor any kind of discharge from the throat, nose, eyes, ears, etc., nor any albuminuria." Wherever possible, a bacteriological examination of the nose and throat secretions of a scholar that has had diphtheria should be made from time to time, and his return to school should only be permitted when two successive examinations no longer show the presence of the specific organism in the secretions mentioned. Rules and regulations like the above, when promulgated, "should have the force and authority of law, and should be enforced, if necessary, by the entire power, including school officers, etc., of the State."[1]

Boarding-schools and similar institutions should have an infirmary where contagious diseases may be isolated, and those in charge should make that isolation from other scholars and inmates as complete as possible. At the beginning of a term it may be well to subject scholars who have been exposed to contagion to a postponement of attendance until the probable period of incubation for the special disease is passed, the period dating from the time of exposure and subsequent disinfection of clothing, etc. With the above precautions it will rarely be necessary to close a school unless a disease is markedly epidemic and malignant.

[1] Recent investigations have shown that the purulent discharge from the ear that so often follows attacks of measles and scarlet fever, and less frequently, of diphtheria, may be highly infectious and a positive agent in disseminating the respective maladies. Consequently children should be excluded from schools until this sequel of disease as well as others has entirely disappeared.

REQUIREMENTS OF PHILADELPHIA BUREAU OF HEALTH IN COMMUNICABLE DISEASES.

Disease.	Placard.	Period of quarantine (from the date of reporting to Bureau of Health).	Period of exclusion of patient from school.	Period of exclusion of other school children from infected house.	Exclusion of wage earners from work.	Closing of places of business.
DIPHTHERIA . . .	Yellow	At least 14 days and 2 negative cultures from nose and throat on 2 successive days.	At least 14 days, antitoxin and upon 2 negative cultures from nose and throat on 2 successive days; 21 days if no antitoxin.	*Remaining at home.* At least 14 days, antitoxin for immunizing, and one negative culture. When case is terminated and disinfection. *Not immunized,* at least 21 days.[1]	*During period of quarantine,* unless a negative culture, disinfect clothing and removal from home.	*All places selling food,* also where good isolation and rules are not observed.
SCARLET FEVER . .	Yellow	35 days.	During quarantine at least 35 days, no discharge or desquamation.	During quarantine at home. Removal from home and disinfect clothing, in 10 days, if immune by previous attack.	During quarantine, unless disinfect clothing and removal to house without children.	Same as above.
SMALLPOX	Yellow	Removal to hospital.	After discharge from hospital.	Vaccination.	Unvaccinated. 18 days of quarantine.	Until disinfected
MEASLES, GERMAN MEASLES, MUMPS, CHICKEN-POX . .	White.	At least 21 days or until well.	At least 24 days or until well.	At least 21 days or until patient is well, disinfect clothing and removal—14 days.	No.	No.
WHOOPING-COUGH .	White.	Until well.	35 days from onset.	No.	No.	No.

After removal from home, antitoxin and negative culture, may return immediately upon disinfection of clothing.
Same without antitoxin may return 7 days after removal and disinfection of clothing.

It is to be hoped that we shall soon have a means of inoculating persons against all contagious diseases, as we now do against smallpox. At present, boards of health and school boards should insist on the vaccination of all school-children. In Illinois, from 1880 to 1883, the deaths from smallpox among unvaccinated children were 48 per cent. of those incurring the disease; among the vaccinated, only 0.9 per cent. In Philadelphia all who desire it are vaccinated free of charge by the vaccine physicians, and it is compulsory for all school-children.

Another great advance in the protection of school children is the employment of the Schick test to discover those susceptible to diphtheria and the administration of the toxin-antitoxin treatment to those giving a positive reaction, this being done, of course, only upon consent of the parents. New York City has taken the lead in this salutary procedure, almost a million of its school children having received the primary test and a very large number the protective treatment without harm or detriment. In fact, some are advocating as a measure of even greater safety that the toxin-antitoxin treatment be administered first, to be followed later by the Schick test to discover the very few who may not have been immunized by the prior inoculation. Whether this plan be adopted or not, there can be no question that many thousands of children throughout the country have already been given a fair measure of protection against this dread disease, and that it is only a question of time until every progressive community shall have adopted and applied it, and also until a somewhat similar method of testing for susceptibility to and protecting against scarlet fever shall have been put into force. In fact, it is said that Zingher has already applied the Dick test for this purpose to 15,000 of the New York City school children.

Lincoln has also suggested that further regulations similar to the following should be in force in every school district: "Every child entering the public schools must show a certificate from some reputable physician, giving name, age, residence, approximate date of vaccination,

date of examination, result of examination; the last two to be of the physician's own knowledge. The fact of vaccination must be entered on the school record and on lists for promotion and transfer. The school authorities shall annually report the number of those not protected to the State Superintendent of Education. School authorities may order the exclusion of non-protected persons, after sufficient notice, where they think the measure required for the public health. Revaccination at the age of fifteen may be required under similar circumstances. Those unable to pay should be furnished with free vaccination by the school authorities. A physician's certificate of protection by a previous attack of smallpox is equivalent to a certificate of vaccination."

Contagious ophthalmia is a disease often prevalent in charitable and educational institutions and occasionally in primary schools, and requires great care to prevent its invasion and spreading, as well as to effect a cure. Those afflicted with it should be quarantined until there is no further discharge or till the granulations on the inner surface of the eyelids have disappeared. Enfeebled health and poor and insufficient food favor its development, but the chief means of contagion is by the use of the same wash-basins and towels by a number of children.

Other diseases that may be transmitted in much the same way are chronic conjunctivitis ("granular lids") and those due to fungous and other parasites, as the tineas ("ringworm of the scalp or face"), pediculosis, etc., all of which may be transmitted by an interchange of hats or caps or other garments.

School children should not be allowed to attend the funerals of companions dead of a contagious disease, nor should funerals be allowed to take place from schoolhouses under any circumstances, owing to the effect on the thoughts and sensibilities of nervous children.

One of the most noteworthy developments in the line of modern public health work is that of school medical inspection. Not only are the troubles of ailing or defective pupils discovered, the attention of parents directed thereto,

corrections of the same brought about and the spread of infectious diseases prevented; but the general welfare of the public at large is enhanced by the physical, mental and moral improvement in the youthful portion of the population that is an inevitable result of the work. As an indication of the importance and extent of such work in a large city, the records in Philadelphia for the calendar year 1913 show a total of 158,974 notices by school inspectors to parents concerning physical defects in the children, of which about 75,000 were for troubles requiring treatment by physicians, and about 64,000 were because of carious teeth requiring dentist's attention. In the same period almost 3,000 contagious and 14,000 parasitic diseases were reported.

The following table indicates the nature of the physical defects recommended for treatment:

Eye-strain	17,506
Other eye cases	7,595
Nose and throat defects	34,522
Ear defects and diseases	2,261
Diseases of teeth	64,238
Orthopedic defects	2,706
Poor nutrition	2,464
Functional nervous diseases	1,111
Heart disease	872
Skin disease (mostly unimportant)	19,833
Accidents, acute illness	2,208
Miscellaneous	3,608

The important part, however, of the report from which the above figures are taken is that in the first seven months of the year 43 per cent. of the defects then reported had been corrected subsequent to the issuance of the inspector's notices, the proportion of defects corrected, classified according to the nature of defect, being as follows:

	Per cent.
Eye	36.0
Ear	61.0
Nutrition	52.3
Heart	53.8
Nose and throat	29.9
Teeth	27.5
Orthopedic	37.8

"Medical inspection in our schools returns large dividends on small investments. Jensen has shown that the cost of a school dental clinic in Germany is only one mark per year per child. The cost saved must be very many times this sum." "Cronin, of New York, maintains that in a school population of 650,000, 30 per cent. of the children were from one to two years behind their proper class. Ninety-five per cent. of these children were so principally because of defects of eye, ear, nose, or throat, which could easily be detected and remedied through effective medical inspection. Experiments at home and abroad have proved beyond any doubt that the majority of children of this sort, when given proper medical treatment, improve markedly in intellect and general conduct. The State attempts to educate these children, but its efforts are, to a large extent, wasted. Osler calculated that in the special city to which reference has been made there was, on account of a lack of medical supervision of educational work, a yearly financial loss of $1,666,666; of course, the loss which came from moral deviation due to defective physical functioning was of far greater importance. He also said, in effect, that he considered it of greater importance to the nation that the question of sound teeth be intelligently considered than that the consumption of alcohol be restricted, important as the latter problem is."[1]

[1] Report on National Vitality, Fisher, pp. 123 and 173.

Readers especially interested in the many and various phases of School Hygiene are advised to consult Cornell's *Health and Medical Inspection of School Children* (F. A. Davis Co.), Newmayer's *Medical and Sanitary Inspection of Schools* (Lea & Febiger), Terman's *Hygiene of the School Child* (Houghton, Mifflin & Co.); Dresslar's *School Hygiene* (Macmillan Co.) and Rowe's *Physical Nature of the Child* (Macmillan Co.) as sources of authoritative and abundant information, and for details that may not be included in the limits of a single chapter.

CHAPTER XII.

DISINFECTION.

As has been stated, disinfection is that part of prophylaxis which has to do with the destruction or modification of the exciting causes of disease, and we may accordingly define a *disinfectant* as "an agent capable of destroying the infective power of infectious material," or, as "an agent which brings about the destruction of bacteria in general, and more particularly of those that act as the exciting causes of disease."[1] Consequently, as with our present knowledge we are practically limited in the use of disinfection to the infectious diseases only, a disinfectant must also be a *germicide*. Theoretically, it should also have the power of destroying the poisonous properties of the toxins which the disease germs produce and which create the characteristic symptoms of the specific diseases, but it is not essential that they do have it, since by killing the germs we check the further production of the toxins; and disinfectants are mainly used not so much to cure or arrest the progress of a disease in a patient as to prevent its incurrence by others.

In a popular sense, the term disinfection is given a wider meaning than is indicated above, one including not only the use of antiseptics and deodorants, but often also the actual removal of filth and all matters favorable to the growth or spread of disease germs, which is, strictly speaking, a matter of sanitation. It is needless to say that the latter work may be part of the prescribed duties of a disinfector, but it is not one of the essential functions of a disinfectant.

[1] Harrington, Practical Hygiene, p. 488.

It will be well here to make the distinction between disinfectants and antiseptics and deodorants, as the terms are often erroneously used interchangeably, and as there is a common belief that whatever is a deodorant or an antiseptic is also a disinfectant. An *antiseptic* is an agent that retards or arrests bacterial growth and the consequent production of toxins or ptomaïns, though it does not necessarily kill the microörganisms themselves; and though some antiseptics are germicidal, others are not, and therefore as a class they cannot be considered or used as disinfectants. But, on the other hand, "agents which kill bacteria in a certain amount prevent the multiplication of the latter in culture-fluids when present in quantities considerably less than are required to destroy vitality." So, a diluted germicide may act as an antiseptic and may be used therefor. For instance, chlorinated lime, which is a good disinfectant in solutions of proper strength, may arrest further bacterial growth or action in a mass of sewage or filth and prevent the latter acting as a culture-medium for disease germs, even though the agent be totally inadequate in quantity to kill all the microörganisms present. In the same way, it may act as a *deodorant*—which, by the way, is an agent that simply removes or destroys offensive odors, and is not necessarily either a disinfectant or an antiseptic—both by checking the further action of saprophytic bacteria and the consequent formation of putrefactive odors, and by actually decomposing and oxidizing those of the latter already formed.

In practical disinfection it is also well to remember that while masses of dead organic matter may not in some cases contain disease germs, and may be even hostile to them, in general the reverse of this is more likely to be true, and decaying matter may furnish a good field for the increase of pathogenic organisms. Moreover, the noxious gases given off to the air and the poisonous products added to a drinking-water from such masses may also do much harm by depressing the system, lower-

ing the vitality, and acting as predisposing conditions to the incurrence of such diseases as cholera, typhoid and typhus fever, diphtheria, etc.; so when time or opportunity

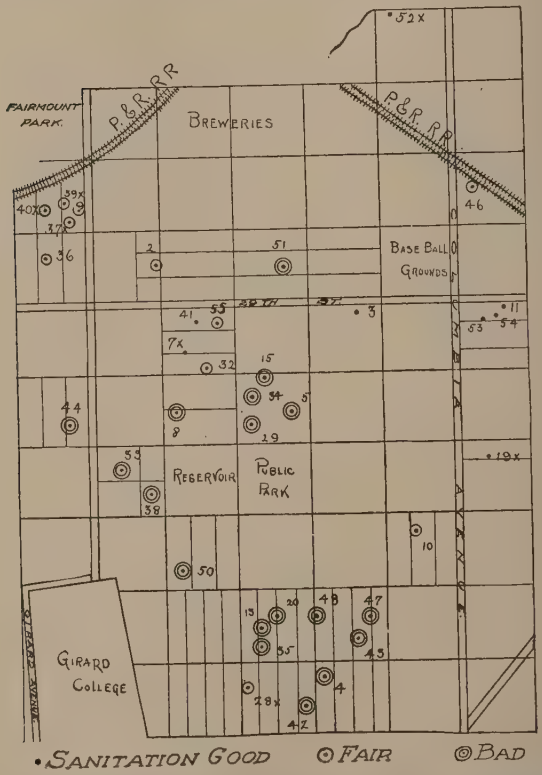


FIG. 96.—Diphtheria and poor sanitation. Chart, showing cases which originated apparently spontaneously and the grade of sanitation of each infected dwelling. (From Cornell's Health and Medical Inspection of School Children.)

does not permit of the removal of such dangerous accumulations, their power for harm should be checked permanently or, at least, temporarily by the use of suitable disinfectants or antiseptics.

But when we are actually dealing with disease germs, disinfection, to be trustworthy, must be carried out to the best of our ability with the means at our command and with strict attention to the minutest details. "There can be no partial disinfection of infectious material; either its infectious power is destroyed or it is not. In the latter case there is a failure to disinfect." This is because the undestroyed living bacteria still have the power of reproduction, and may, within a very short time under favorable circumstances, equal or even exceed the number that was present before the unsuccessful attempt at disinfection was made. In fact, our aim in such prophylaxis must always be "to interrupt all possible paths of disease conveyance, and to exterminate the causal agent."

The knowledge as to the efficacy of any substance as a disinfectant is obtained from the accumulated experiences of practical sanitarians and from experiments on susceptible animals and in culture-media in which infectious matter is treated with that substance. The knowledge gained must stand the test of scientific deduction, and a substance is not a disinfectant simply because, in one given case, infection did not occur after its use. To be of value the deductions must be made from considerable accumulated and practical experience. "Negative evidence should be received with great caution;" but if the experience of practical sanitarians is confirmed by careful culture and inoculation experiments, our knowledge of the value of any agent becomes more definite and our practical work more exact. From such inoculations and experiments it has been found that the infectious germs of different diseases differ in their power to resist the different disinfectants; but nevertheless it may be stated that "in the absence of spores, a disinfectant for one is a

disinfectant for all." Consequently, we are able to simplify and classify the agents at our disposal and to make more effectual use of them.

Some agents that are powerful against all other organisms completely fail to destroy the vitality of spores, and thus our list of disinfectants available in *all* cases is still further reduced. In the case of a disease germ that does not produce spores, as that of diphtheria or typhoid fever, agents may be used that are powerless against spores, but in doubtful cases only those should be used that have the power of spore destruction.

We may classify the disinfectants of which we commonly make practical use as either *thermal* or *chemical*, not forgetting, however, the influence of sunlight or light from artificial sources, especially that which is rich in ultra-violet radiations. As Duclaux has said, "the sun (light) is the cheapest disinfectant known."

There may also be a *mechanical* sterilization, as in the separation of microörganisms from a liquid by filtration or sedimentation, or by their physical removal from very smooth articles by wiping, or from the human skin by thorough scrubbing and washing. The efficiency of the latter depends on the smoothness of the person's skin, the extent of exposure to pathogenic germs, and especially upon the care and thoroughness with which the cleansing process is accomplished.

Lastly, certain secretions and tissues in the body which have the power of destroying infective matters, giving each person more or less immunity against certain diseases, may be termed *physiological* disinfectants.

THERMAL DISINFECTANTS.

Of the thermal disinfectants, *fire* is the most efficacious, as it destroys all organic matter, but it can only be used to disinfect non-combustible articles or those that are of little value and that cannot be safely disinfected in any other way. For instance, as it will usually cost

more than they are worth thoroughly to disinfect by other methods used dressings from wounds or old mattresses, etc., that have been used in infectious cases, it is best to burn them.

All things considered, *steam* is probably the most practical and efficient disinfectant, as it is cheap, easily used and manipulated, and is less liable to injure the articles to be disinfected. We employ it under pressure, when its temperature is correspondingly increased, or in the streaming state (live steam), the latter being as efficient as the

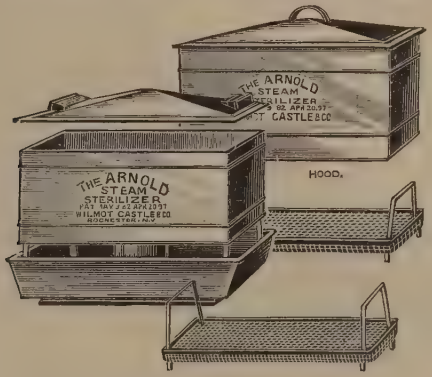


FIG. 97.—Steam sterilizer for small articles.

former, but sometimes requiring a little longer time. For instance, steam at 240° F. is said to kill the most resistant spores very quickly, and streaming steam at 212° F. will produce the same effect within thirty to forty minutes. In fact, under very favorable conditions, probably few, if any, of the ordinary pathogens can withstand the temperature of boiling water (212° F.) longer than a few minutes, but it is always wise to employ sufficient time and heat to remove any possibility of doubt or danger. One should also remember that for surface disinfection streaming, saturated steam is relatively much more efficient

than superheated steam, on account of the great liberation of latent heat when the former condenses, and possibly because the latter tends to dry rather than moisten the organisms and thus render them harder to disinfect. As a sanitary precaution and to prevent the spread of epidemics, special apparatus for disinfecting large articles by steam is now established in almost every large city and many hospitals by the municipal authorities and others.

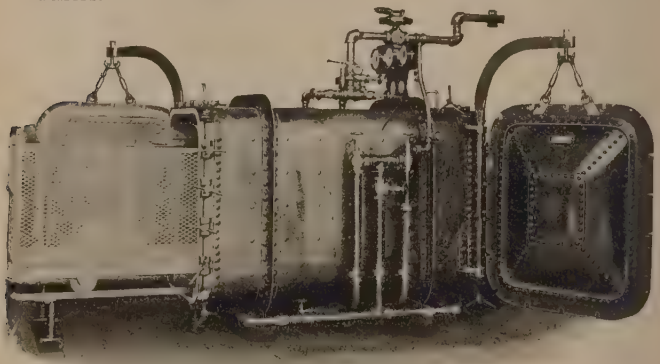


FIG. 98.—Steam disinfecting chamber for clothing, bedding, and other large articles.

In steam sterilization, as with all other disinfectants, the aim must be to bring the germicidal agent into contact with every part of the infected matter; in other words, to secure thorough penetration. The size and compactness of the articles to be sterilized accordingly govern in part the duration of their treatment by the steam. Steam under pressure is, of course, more penetrating than live steam, and is especially expeditious when the apparatus is so arranged that the air can be exhausted from it and a vacuum created in the interstices of the articles to be disinfected before the steam is introduced.

In the large sterilizers constructed for hospital or municipal use every precaution is taken to prevent the reinfection of articles after they have been once sterilized. The goods enter the apparatus at one end, and after the treatment are taken from it at the other end, being handled and delivered to their owners or destination by an entirely different group of employés and conveyances than those concerned with them before the disinfection. The apparatus is built into a closed partition, which entirely separates the two parts of the disinfecting building and prevents any transmission of germs from the infected to the disinfected side, especially as the doors of the sterilizer are, or should be, so arranged that they cannot both be open at the same time.

BOILING-POINT OF WATER UNDER STEAM-PRESSURE.[1]

Steam-pressure (pounds).	Boiling temperature. (F.)	(C.)
0	212°	100.0°
5	228°	109.0°
10	240°	115.5°
15	251°	121.5°
20	260°	126.5°
40	287°	141.5°

In the absence of spores, bacteria are killed by *hot water* even below the boiling-point, and it is safe to say that boiling for ten or fifteen minutes will kill all known disease germs, especially if from 1 to 2 per cent. of washing soda or a little common salt (sodium chloride) be added to the water; although spores of certain harmless bacilli are said to have resisted boiling for several hours. The addition of soda also prevents the rusting of iron or steel instruments, but is likely to cause erosion of aluminum articles. In the absence of chemical disinfectants, boiling water may be used to disinfect excreta, etc.; and

[1] McFarland and Babcock, in Cohen's System of Physiologic Therapeutics, vol. v, p. 201.

all clothing worn by the sick or the attendants upon the sick should be well boiled before using again, whether other disinfectants are employed or not.

Dry heat is far less penetrating and less effective than moist, and must accordingly be used at much higher temperatures and for a longer time. At 300° F. dry air will require at least three or four times as long to do what steam at 212° or 220° F. will do, and, moreover, at such high temperatures it is very apt to injure clothing or other organic materials exposed to it for so long a time as is necessary. Consequently, it is only to be used to disinfect articles that would be injured by moisture or chemicals, and even then it is better to employ the "fractional" method of disinfection—*i. e.*, exposure to high temperatures for short periods only, but for a number of times, with sufficient intervals between the exposures to allow the development of any spores that may possibly be present.

Contrary to the popular opinion, cold is not a positive germicide, or at best is but a slowly acting one. Typhoid germs have been frozen for more than one hundred days without all of them losing their power for harm, and various microörganisms have withstood the temperature of liquid air—below −300° F.—for several hours or days. However, freezing, especially if intermittent, tends to prevent the growth of bacteria, and they gradually decrease in number in frozen material.

In this connection it is not out of place to refer again to the germicidal power of *light*, especially sunlight, and to its value as an adjunct in the disinfecting of rooms, clothing, etc. It is an agent that may be used progressively and efficiently in the sick-room throughout the course of an infectious disease; and psychically, as well as otherwise, adds to the cheer and comfort of the patient rather than to increase his discomfort, as does the use of most other means to the same end.

CHEMICAL DISINFECTANTS.

Regarding the chemical disinfectants, it must be remembered that it requires a certain amount of each to disinfect a given quantity of bacteria, and also that, with all disinfectants, time is an important element, as none act absolutely instantaneously. Heat, however, facilitates and increases the rapidity of action of the chemical disinfectants.

Another caution to be observed is that the disinfectant should always be of sufficient strength in the *mixture* with infected material. For example, if a disinfectant is only effective in 1 per cent. strength or more, then at least a 2 per cent. solution should be added, volume for volume, to the matter to be disinfected, and should be thoroughly mixed with the latter in order that the germicide may be brought into contact with all the infective organisms.

Chlorinated Lime.—Chlorinated lime (often called chloride of lime) is one of the best and cheapest disinfectants. It should contain at least 35 per cent. of available chlorine, should be kept covered from air and moisture, and fresh solutions should always be made as needed. Its power is due to hypochlorite of lime, which is freely soluble in water and readily dissociates in contact with organic matter, giving up chlorine gas—a most powerful disinfectant—and also liberating nascent oxygen that in turn acts powerfully upon the organic matter present, including living microörganisms. "Germs of all kinds, including the most resistant spores, are destroyed by this solution; but it must be remembered that the disinfectant itself is quickly decomposed and destroyed by contact with organic matter, and that if this is present in excess, disinfection may not be accomplished, especially when the germs are embedded in masses of material which are left unacted upon after the hypochlorite of lime has been all exhausted in the solution." Labarraque's solution of *chlorinated soda* is also an effective mild disinfectant, but does not keep well, and chlorinated lime is

equally good and much cheaper. However, the soda solution has scarcely any disagreeable odor, and makes a pleasant disinfecting bath for the person. The official solution must contain at least 3 per cent. of available chlorine, but it may be diluted with from two to five parts of water before use, especially for bathing.

"Though probably effective against sporeless bacteria in somewhat less proportions, solutions of chlorinated lime should be of at least 1 per cent. strength by weight, and should be used in excess, to allow for both the dilution by the mass to be disinfected and the exhaustion of the hypochlorite by organic matter. "In the U. S. Army a 4 per cent. strength of chlorinated lime in solution is officially prescribed for use in disinfection of the excreta of the sick, it being specifically stated that the chlorinated lime so used shall be of good quality and not have undergone decomposition."[1]

Bichloride of Mercury.—Bichloride of mercury (corrosive sublimate) is one of the best germicides that we have, and is effective in comparatively weak solutions. It corrodes metal, and so cannot be used to disinfect waste-pipes, etc.; and it combines with and coagulates albumin, which interferes somewhat with its action. This coagulation is prevented to a degree by the addition of a small amount of citric or tartaric acid to the solution, which addition also favors the solution and, as was first shown by Laplace, increases the efficiency of the mercurial salt. The same result is said to be obtained if one part of hydrogen peroxide (15 per cent. solution) be added to three parts of a corrosive sublimate solution of any strength. Common salt (0.5 to 1 per cent.) or ammonium chloride when added to twice the quantity of corrosive sublimate increase its solubility, but they are said to diminish its efficiency somewhat. However, it is better not to use corrosive sublimate in disinfecting fecal excreta or sputum, as these always contain more or less albumin, and

[1] Rosenau's Preventive Medicine and Hygiene, p. 1019.

also because the sulphur present in the excreta permits the formation of a sulphide of mercury, which has almost no power as a disinfectant. A lime solution is better and more certain.

Bichloride of mercury should be used in solutions of from 1 in 1000 to 1 in 500 strength for ordinary disinfection, though weaker preparations are sometimes used in surgical cases. It is especially valuable where a large amount of fluid is to be freely used, but on account of its poisonous properties and the consequent danger of accident from a lack of color, stock solutions should always be colored by adding a little aniline dye or copper sulphate. Abbott cautions that the stains of blood and feces on clothing are rendered almost indelible by long soaking in bichloride solutions. Silver nitrate is almost, if not fully, as good a disinfectant as bichloride of mercury, and does not coagulate albumin so readily, but is much more expensive and has the objectionable property of permanently staining many things.

Carbolic Acid.—Carbolic acid is effective in the absence of spores, and, according to Koch, should have first place in disinfection against the cholera germ. It is of doubtful value, however, in cases of typhoid fever, as it is said that the typhoid bacilli can be cultivated in a medium containing 0.5 per cent. of carbolic acid; nor is it reliably efficient against spore-forming organisms.

Solutions should always be made by first dissolving the acid in hot water, and should contain from 2 to 5 per cent. of acid, the latter being practically a saturated solution. The addition of a small quantity of glycerin is said to facilitate the solution. The stronger solution is especially valuable for the direct disinfection of human excreta of all kinds, but must be thoroughly mixed with the same, as carbolic acid coagulates albumin, though not to the degree caused by bichloride of mercury; while the weaker fluid (2 or 3 per cent.) may be used freely for the disinfection of clothing or the washing of walls, floors, furniture, etc. A 2 or 3 per cent. solution of a mixture of equal

parts of carbolic and sulphuric acids is valuable for the disinfection of water-closets, urinals, etc., as the latter acid increases the effectiveness of the mixture; but it must not be kept too long in contact with metals on account of the corrosive action of the sulphuric acid. Rosenau states that the addition of 0.5 per cent. of hydrochloric acid to carbolic acid aids its activity.

Solutions of the *cresols* (meta-, para-, and ortho-), which are derived from coal- or wood-tar, and much resemble carbolic acid, may be used for the same purposes and in about the same strength as solutions of the latter. In fact, *tricresol*, which is a refined combination of the three, is two or three times as powerful a disinfectant as carbolic acid, and, in solutions of from 0.5 to 1 per cent. strength, makes an agreeable and efficient disinfectant for use in surgery and obstetrics, especially as it does not coagulate albumin as readily as do carbolic acid and corrosive sublimate. As carbolic acid and cresol solutions are all poisonous, they should always be so labelled, although the characteristic odor serves as a partial safeguard to those accustomed to it.

The cresols do not corrode metals and can be used with soaps and oils to form emulsions, both of which features increase their usefulness for surgical and other purposes.

Creolin.—Creolin is another coal-tar product that has some germicidal power, but is not so efficient as was formerly credited. Being cheap, it may be used freely for disinfecting drains, stables, urinals, and such places where its rather strong odor is not objectionable. It should be made up in from 2 to 5 per cent. strength in water, and, being insoluble, the mixture must be thoroughly stirred or shaken each time before use.

As McClintock and Frey have shown that most of the coal-tar disinfectants, including carbolic acid and the cresols, do not destroy the virulence of vaccine virus in the strength and time in which they kill practically all non-spore-forming bacteria, "the inference is allowable that this class of disinfectants is not safe to use for

such diseases as smallpox and the presumably protozoal diseases, such as syphilis, measles, etc."[1]

Zinc Chloride.—Zinc chloride is a good antiseptic and deodorant, but not a very powerful disinfectant. A 5 to 10 per cent. solution will kill germs without spores.

Calcium Hydrate.—Calcium hydrate, when mixed with water to make a thin whitewash (milk of lime), is said to be a good disinfectant, especially for excreta, etc., and is one of the cheapest and easiest to obtain. It should be added to the infectious matter in excess or until the mixture is decidedly alkaline, and will require from one to two hours to disinfect thoroughly.

The proportion of lime to water should be about as 1 to 4, equal parts being first taken to allow the slaking of the lime, and the rest of the water then added and the mass thoroughly mixed by stirring. Two quarts of this mixture per day for each person using a cesspool will keep the contents of the latter disinfected and free from putrefactive odors, provided its use commences with the use of the cesspool, or that the prior contents have been disinfected by an excess of this or a chlorinated lime solution, or by an abundance of the latter salt or quicklime in powder. Air-slaked lime should not be used to make up the "milk of lime," as it is practically worthless, but the lime should always be freshly slaked with water as indicated or else kept in an air-tight container after such slaking.

Sulphate of Iron.—Sulphate of iron, which acts as an antiseptic to prevent putrefaction, rather than as a disinfectant, may also be added to the contents of an offensive cesspool or one that has received infected matter to the extent of about four pounds for each cubic yard of the mass. The sulphate should, of course, be thoroughly dissolved before using.

Hydrogen Peroxide or Dioxide.—An extremely valuable disinfectant for local or topical applications to the person

[1] Rosenau, loc. cit., p. 1012

is hydrogen peroxide or dioxide (H_2O_2). It is harmless, even when taken internally; is effective in comparatively weak solutions, and is especially active in the destruction of pus organisms. It is usually supplied in the form of a 15 per cent. solution in water and at present only its high cost prevents its more extended use.

Chlorine and Sulphur Dioxide.—Until the discovery, in 1892, of the great disinfecting power of formaldehyde or formic aldehyde by Trillat and Aronson, about the only gaseous disinfectants of practical value were chlorine and sulphur dioxide.

Of these, chlorine is the more powerful and efficient, but the distressing and oftentimes serious symptoms which it produces when accidentally inhaled, and the bleaching effect that it has upon many articles, have both tended to prevent its common employment. Like the sulphur dioxide, it acts best in the presence of moisture, and therefore steam should be simultaneously introduced and liberated in the room or enclosure in which either of these disinfectants is used. Sufficient chlorine for 1000 cubic feet of space may be generated by carefully pouring two fluidounces of strong sulphuric acid and three fluidounces of water, previously mixed and cooled, upon eight ounces of sodium chloride (common salt) and two ounces of manganese dioxide. The acid must be added to the water little by little and with care, and the salt and manganese should be in an earthen vessel upon a bed of sand, to prevent injury to the floor or carpet. Moreover, as the chlorine gas is very heavy, the generating apparatus should be at as high a level as possible in the room to get even fair diffusion.

Sulphur dioxide (SO_2), though not so positive in its action as chlorine, is more frequently employed on account of the lesser risk and trouble connected with it. It probably kills germs not containing spores if sufficiently concentrated and in the presence of moisture, and is therefore useful in the fumigation of rooms and of articles that cannot be subjected to steam-heat or chemical solu-

tions. But it will bleach or tarnish many articles, and for this reason and the fact that it is thought by some to be inferior to formaldehyde, its use has been in a measure supplanted by that of the latter whenever that could be obtained.

To secure sufficient concentration at least three pounds of sulphur should be burned for every 1000 cubic feet of air-space.

The sulphur should be well moistened with alcohol, unless the prepared sulphur candles now on the market are used, and allowance should be made for a considerable proportion that is usually not burned. Care must also be had to guard against setting fire to the room from the sputtering of the sulphur, and especially to have present in the atmosphere an abundance of aqueous vapor.

Before the fumigation of a room with chlorine or sulphur dioxide, or with formaldehyde, all apertures and crevices in the walls, ceiling, or floor should be carefully closed from the outside to maintain the gases in as concentrated a state as possible during the process, which should continue for at least twenty-four hours in the case of chlorine or sulphur gas, and for not less than twelve hours with formaldehyde. After the fumigation the room should be thrown open and well ventilated, and then thoroughly cleansed with a corrosive sublimate, carbolic acid, or hot soda solution, a 4 per cent. solution of the latter being not only cleansing, but strongly disinfectant as well.

Sulphur gas excels formaldehyde in the destruction of such vermin as roaches, bed-bugs, fleas, flies, and mosquitoes, and may be preferred to the latter or used as an adjunct to it where there is danger of infection being transmitted by these agents. Likewise, it may be used to destroy larger animals, such as rats and mice, that we now know may be carriers of various disease germs. (See p. 427.)

Hydrocyanic acid, which may be freely liberated as a gas by the addition of dilute sulphuric or hydrochloric acid

to cyanide of potassium or sodium, has been used both as a germicide and an insecticide. Its high relative cost does not warrant its use as a substitute for sulphur-gas or formaldehyde, but the certainty with which it kills all kinds of small vermin, and even higher animals, such as rats and mice, that may carry infective organisms, renders it of high value for this purpose. Its poisonous nature, however, should always be remembered, and great care always observed in its use.

Formaldehyde.—Formaldehyde (formic aldehyde), both in its gaseous state and in solution, is undoubtedly one of the best and most efficient disinfectants now in use. It has considerable penetrating power, although less than steam or than was claimed for it at first by its more enthusiastic advocates, while for surface disinfection it acts almost immediately. It is much better in this respect than chlorine or sulphur dioxide, already mentioned, and where it is properly used, only such articles as bedding, mattresses and pillows, that can be better treated with steam, need be removed from an infected apartment. Clothing, rugs, hangings, etc., that can be freely exposed to it are quickly sterilized. Another important feature is that it does not corrode or tarnish metals nor bleach or act destructively on either clothing or furniture, and that, although it is quite irritating to the conjunctivæ of the eyes and to other mucous membranes when concentrated, it is virtually non-poisonous.

Formaldehyde is readily absorbed and held in solution by water to the extent of 40 per cent. by weight of the latter, but as soon as this proportion is exceeded there is a polymerization of the gas and a solid (paraformaldehyde or paraform) is precipitated, which is only resolved again into formaldehyde at a temperature of 275° F. The 40 per cent. solution is practically identical with the preparation which is commercially known as formalin, which has usually an addition of 10 per cent. of methyl alcohol as an additional safeguard against precipitation. Very weak solutions (1 or 2 per cent.) of the gas are still

effectively disinfectant, while its virtue as an antiseptic persists even when the dilution is carried to a remarkable degree.

One peculiar effect of the solutions is that of rendering connective tissue and all gelatinous substances insoluble in either hot or cold water, and it is probably to this that its germicidal activity is largely due, since the food-supply of the bacteria, if not the substance of the latter themselves, is partly of this nature. For the same reason it hardens and disagreeably roughens the skin, which tend to prevent its use for topical applications to the human body.

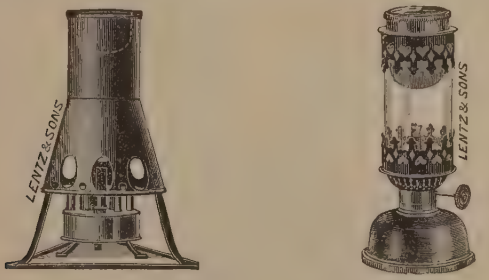


FIG. 99.—Schering's lamps for volatilizing paraform.

Several methods have been devised for the production or liberation of formaldehyde in rooms and buildings in such volume as positively to secure both surface and penetrative disinfection. One of the first devised and best methods involves the heating and vaporizing of a solution of gas, such as formalin or formochloral, the latter a mixture of the former with calcium chloride. For instance, in Trillat's apparatus the latter solution is used, the calcium chloride being added to insure against the precipitation of paraform. A simpler device, called a regenerator, allows formalin to flow in a fine stream through a copper coil heated to redness by a flame beneath, the gas and vapor then passing directly into the

room in a superheated and effective condition; and in other apparatus, like the Novy-Waite and Trenner-Lee generators, there is special provision for the rapid evolution of the gas at high temperature and to prevent its polymerization. Both of these methods have the advantage that the apparatus may be operated outside of the room to be disinfected, and the action accordingly controlled;

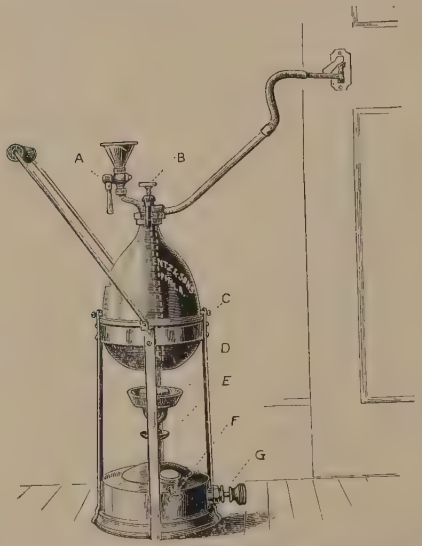


Fig. 100.—Modified Novy-Waite formaldehyde generator.

also that the amount of gas liberated depends directly upon the strength and quantity of the solution evaporated.

In the Schering method the solid paraform is heated in a receptable over an alcohol lamp, the volume of resulting formaldehyde depending, of course, upon the amount of paraform used. This method has yielded some excellent results experimentally, and is of special value

in disinfecting small rooms, closets, and sterilizing cases for instruments, dressings, etc.

The gas may also be liberated in a room by spraying formalin from a properly constructed compressed air or steam atomizer, or by evaporating it from saturated sheets hung about the room, but as this is not certain to liberate all the gas from the solution, more of the latter must be used.

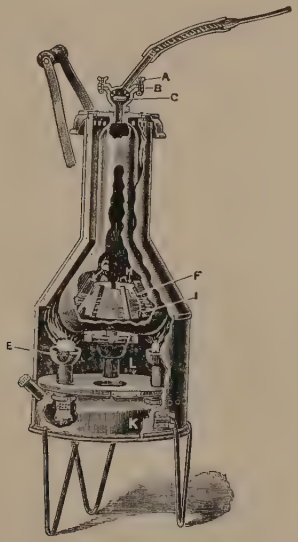


FIG. 101.—The Trenner-Lee formaldehyde generator.

Formerly a very common type of apparatus was that devised in the form of a portable lamp to develop the gas directly by the oxidation of methyl alcohol, the vapors of the latter being made to pass over or through tubes or coils of heated platinum, and to be thus converted into the disinfectant gas. Considerable formaldehyde can

doubtless be produced in this way, but with most apparatus of this kind the amount at any time is uncertain and the results indefinite, since part of the alcohol vapors are polymerized and part are further oxidized into compounds such as carbon monoxide and carbon dioxide. Therefore, with such apparatus, this method is, as a rule, only to be advised for comparatively small apartments or enclosures, and not where certainty of disinfection is important. However, these objections have been overcome in the Kuhn generator, which is simple and positive in operation and manipulation, and has been proved efficient and reliable under severe tests.

Abbott states that he has "obtained the most satisfactory results through the use of formalin to which 10 per cent. of glycerin has been added, as recommended by Schlossmann; and through the employment of a generator after the plan of that advised by Novy and Waite. In these tests we found that 80 per cent. of all exposed infected objects in a room could be disinfected when 500 c.c. of the formalin-glycerin mixture per 1000 cubic feet of air-space was completely evaporated and the room kept closed for three or four hours."[1]

In the other apparatus one pound of formalin or formochloral, from 50 to 75 of Schering's paraform tablets, or a quart of methly alcohol are to be respectively used for each 1000 cubic feet of air-space to be disinfected.[2]

A very simple method of liberating formaldehyde-gas and one whose efficacy, it is asserted, has been thoroughly established by laboratory tests, is to pour one pound of formalin containing 40 per cent. of formaldehyde on eight ounces of permanganate of potash in a high vessel, this being the proper amount for 1000 cubic feet of space or less. The gas is liberated freely and speedily, and with but little risk of polymerization or of any remaining in solution. Of course the effectiveness of action will be

[1] Hygiene of Transmissible Diseases, 1899, p. 269.
[2] See also U. S. Quarantine Regulations, as quoted on p. 361.

enhanced by the previous or coincident vaporizing of water in the room.

Whenever formaldehyde is employed as a gas, all the apertures in the room should be carefully and tightly closed, since, having the same specific gravity as the air, its diffusion takes place rapidly. Moreover, after a sufficient volume of the gas has been liberated, it should be allowed to act as long as possible, preferably for twelve hours at least, and better for twenty-four, since, though it is more rapid, the time element is just as important a factor with this as with other gaseous disinfectants. Flügge thinks we obtain good results if 90 per cent. of the disease germs present are killed by the formaldehyde fumigation. Lastly, the gas is an excellent deodorant, combining as it does with the effluvia from decomposing substances to produce odorless compounds. Its odor, in turn, may be quickly dissipated from a room by evaporating a little ammonia therein.

The following table of Koch and Jaeger is added to show the comparative disinfectant strength of some substances occasionally used for the purpose:

Disinfectant.	Strength.	Objects submitted to experiments.	Time required for destruction.
Bichloride of mercury	1 to 20,000	Anthrax spores	10 minutes.
	1 to 1,000	Anthrax spores	1 minute.
Silver nitrate	1 to 12,000	Anthrax spores	70 hours.
	1 to 4,000	Cholera and typhoid	2 hours.
	1 to 2,500	Diphtheria	2 hours.
Acid, hydrochloric	2 to 100	Anthrax spores	10 days.
Acid, sulphuric	2 to 100	Anthrax spores	53 days.
	15 to 100	Anthrax spores	8 days.
Ferrum chlorate	5 to 100	Anthrax spores	6 days.
Calcium chloride	5 to 100	Anthrax spores	5 days.
Potas. perman.	5 to 100	Anthrax spores	1 day.
Caustic lime	0.0246 to 100	Cholera	6 hours.
	0.0074 to 100	Typhoid	6 hours.
Acid, carbolic	3 to 1,000	Staphylococcus and Streptococcus pyog.	8–11 seconds.
	10 to 100	Anthrax spores	24 hours.
Formaldehyde (K. Walter.)	1 to 100	Nearly all pathogenic germs	Less than 30 minutes.
	3 to 100	Anthrax spores	15 minutes.
		All other pathogenic germs	1 minute.

In any case of infectious disease special attention should be given to disinfecting the excretions and secretions which are known to be most likely to contain the disease germs, viz., the desquamating epithelium and likewise the renal secretion in measles, scarlet fever, and all the exanthemata; the dejecta and urine in typhoid fever, cholera, tropical or infectious dysentery, and in tuberculosis of the intestinal or genito-urinary tract; the sputum in tuberculosis of the lungs and air-passages, and in influenza, pneumonia, and diphtheria; secretions from the throat and nose in diphtheria, scarlet fever, measles, infantile paralysis and cerebrospinal meningitis; discharges from abscesses, suppurating or gangrenous wounds, etc.

During the course of the illness there should be no more communication than is absolutely necessary between the occupants of the sick-room and those in the rest of the house, and a sheet should be hung at the door and kept moist with some disinfecting solution, as this will largely prevent the escape of infective dust particles through the doorway and will especially serve as a warning to outsiders to refrain from entering the sick-room. All articles going from the room, whether dishes, clothing, or food, should be submerged in a disinfectant or covered with a cloth wet with it, and should be burned, boiled, or otherwise disinfected as soon as possible thereafter. Excreta should be disinfected as soon as discharged from the body, but should not be emptied into a water-closet, sewer, or cesspool till the disinfectant has had ample time to do its work, at least one hour being given for this action. Ventilation should be as perfect as possible; sunlight should be admitted whenever it will not injure or annoy the patient, and, above all, cleanliness in every respect should be insisted upon as being most essential. Sick-rooms should be well screened to prevent the access of flies, as these may carry infection to others from sputum, excreta or even the body of the patient.

The dress of the nurse or attendant should be such that dust and germs do not readily adhere to it and that

it may readily be disinfected and cleaned, the cotton uniforms of a hospital training school being almost ideal in this respect. If this were in the form of an overgarment that could readily be slipped off when the nurse has to leave the sick-room, there would be an additional element of safety, just as there will be if there is provided something like the long, old-fashioned linen "duster" for the casual visitor, whether physician or parent, to slip on when entering the room. The nurse should, of course, bathe not only the patient but herself as well with disinfectant solutions, such as Labarraque's (diluted), carbolic acid, or tricresol, and should take particular care to wash her hands each time after ministering to the patient in any way; should destroy at once all possible infection coming from the patient, and at least every other day should wipe with a cloth dampened in a disinfectant all window-sills, tables, and other surfaces upon which dust and the attached germs continually settle. A closet with a close-fitting door may be made to serve as a good disinfecting chamber for garments that are not in immediate use, as a few ounces of formalin sprinkled on the garments themselves or a few paraform tablets burned in one of the Schering lamps will quickly sterilize the contents of the closet without serious discomfort to the occupants of the adjoining room.

It is taken for granted that, if possible, before the occupancy of the room by the sick, all upholstered furniture, heavy drapery and everything not absolutely necessary were removed from the room. Even the carpet should be taken up and rugs used temporarily in its place. If this is done, the work of disinfecting the room after it is no longer needed by the patient will be greatly facilitated.

Since Chapin and others have shown the great preponderance of infections by contact, or through intimate personal relationships, final disinfection after a case of illness is deemed of less importance than it was formerly considered to be. Nevertheless, it should be looked upon as an additional factor in preventing the further

spread of infection, and should be carried through with the same thoroughness that should be observed in other methods of disinfection.

Where the use of formaldehyde is not available, the final disinfection should be carried out as follows: All bed-clothing, etc., should be either submerged in some disinfectant solution or in boiling water, or else covered with a sheet wet with a disinfectant, and boiled as soon as possible thereafter. No clothing should be sent away from the house to be laundered. Bed-quilts, blankets, mattresses, etc., should be subjected to steam sterilization if possible; if not, the blankets and quilts should be carefully sterilized by boiling, and the mattresses had better be burned, though, if in good condition and of some value, they may be disinfected internally by the introduction of formalin or formaldehyde gas, and externally by wiping and wetting with a strong solution of corrosive sublimate. The carpet or rugs should be carefully taken up, carried to an open space, well beaten, and then hung in the open air for a time, provided they cannot be sent at once to some place where steam sterilization is available. All furniture and the woodwork of the room should be washed with corrosive sublimate solution (1 to 1000 or 500), taking care to get the fluid into all crevices. The floor may be scrubbed with lye or hot soda solution (4 per cent.), and then mopped and flooded with the corrosive sublimate solution. The walls should also be wiped with cloths wrung out of this solution, and any paper upon them removed after fumigation, unless it be new and free from cracks. Or the walls may be rubbed down with crumbs of bread and the latter burned, as the bread contains much gluten to which the dust and bacteria adhere. Fumigation with sulphur dioxide is usually of somewhat doubtful efficiency unless considerable attention is given to the details. If it is employed, it should be done first, before the bedding, etc., is removed and the walls, floors, and woodwork are wiped or washed, and all openings from the room, cracks, crevices, etc., should be closed

by sealing on the *outside*, and sufficient gas liberated by suitable means. The vessels containing the gas-generating substances should be placed in larger vessels containing water to avoid the danger of fire, and vapor of water should be liberated in some way simultaneously with the gas, say by placing hot bricks or the like in the water, or else water should be sprayed freely from an atomizer over everything in the room, as sulphurous acid has little disinfecting value except in the presence of moisture, which also greatly enhances the effects of formaldehyde. The room should then remain closed for twenty-four hours, and, lastly, should be well ventilated for a day or two before being furnished and occupied again.

Should it be possible to use formaldehyde, the disinfection is much simplified, and is to be carried out in the way already indicated; but whatever the gaseous disinfectant employed, it should always be followed by the washing or wiping of walls, ceilings, floor, and all exposed surfaces with a disinfectant solution, and by the steam sterilization or boiling of all removable articles wherever possible. In fact, it should be remembered that no one of these processes will in any probability destroy all the infection, but that each must be carried out with conscientious thoroughness and strictest attention to detail in order to secure the greatest measure of success.

Where flies, mosquitoes or other germ-carrying vermin are possibly present, it may be advisable to follow the fumigation by formaldehyde with another by sulphur dioxide, as the latter is much the more certain to kill both insects and rodents. The gas from 1 pound of burning sulphur per 1000 cubic feet of space should kill flies and mosquitoes within two hours; that from 2 pounds should kill rats within four hours, and that from 5 pounds should kill bed-bugs, lice, etc., within six hours.

The United States Quarantine Regulations, promulgated March 22, 1920, authorize the following disinfectants and the methods of generating and using them:

Physical Disinfectants. – **Burning.** – Of unquestioned efficiency, but seldom required.

Boiling.—Very efficient and of wide range of applicability. The articles must be wholly immersed for not less than ten minutes in water actually boiling (100° C.). The addition of 1 per cent. of carbonate of soda renders the process applicable to polished steel, cutting instruments or tools.

Steam.—(*a*) *Flowing steam* (*not under pressure*). Flowing steam (not under pressure) when applied under suitable conditions is an efficient disinfecting agent. The exposure must be continued thirty minutes after the temperature has reached 100° C.

(*b*) *Steam under pressure without vacuum.* Steam under pressure will sterilize, provided that the process is continued twenty minutes after the pressure reaches 15 pounds per square inch. The air must be expelled from the apparatus at the beginning of the process. If impracticable to obtain the designated pressure, a longer exposure will accomplish the same result.

(*c*) *Steam under pressure with vacuum.* Steam in a special apparatus with vacuum attachment is the best method of applying steam under pressure, the object of the vacuum apparatus being to expel the air and to promote the penetration of the steam. The process is to be continued for twenty minutes after the pressure reaches 10 pounds to the square inch.

Chemical Solutions.—*Bichloride of Mercury.*—Bichloride of mercury is a disinfectant of undoubted potency and wide range of applicability. It cannot be depended upon to penetrate substances in the presence of albuminous matter. It should be used in solutions of 1 to 1000. The solubility of bichloride of mercury may be increased by using sea-water for the solution, or by adding 2 parts per 1000 of sodium or ammonium chloride to the water employed.

Carbolic Acid.—Carbolic acid in the strength of 5 per cent. may be substituted for the bichloride of mercury, and

should be employed in the disinfection of the cabins and living apartments of ships to obviate injurious action on polished metals, bright work, etc.[1]

Formalin.—Formalin containing 40 per cent. of formaldehyde may be used in a 5 per cent. solution as a substitute for bichloride of mercury or carbolic acid, and is useful for the disinfection of surfaces, dejecta, fabrics, and a great variety of objects, owing to its non-injurious character.

Gaseous Disinfectants.—Sulphur Dioxide.—Sulphur dioxide is efficient, but requires the presence of moisture. It is only a surface disinfectant, and is lacking in penetrating properties. An atmosphere containing 4.5 per cent. can be obtained by burning 5 pounds of sulphur per 1000 cubic feet of space. This amount would require the evaporation or volatilization of about one pint of water. In the above proportion it may be used as a disinfectant for some quarantinable diseases, as smallpox and cholera. Its principal use in maritime quarantine is in the destruction of disease-carrying vermin, rats, fleas, lice, mosquitoes, etc. For this it is a very efficient agent, ranking next to hydrocyanic acid gas.

The sulphur may be burned in shallow iron ovens (Dutch ovens) containing not more than 30 pounds of sulphur for each pot, and the pots should stand in vessels of water. Quicker and better results can be obtained from burning the same total amount of sulphur in a number of small, shallow ovens (Dutch ovens), 5 to 10 pounds in each, than in a few large ovens. The sulphur ovens should be elevated from the bottom of the compartment to be disinfected in order to obtain the maximum possible percentage of combustion of sulphur. The sulphur should be in a state of fine division, and ignition is best accomplished by alcohol; special care to be taken with

[1] The carbolic acid should be mixed with an equal volume of alcohol before adding to the water: thus to make a 5 per cent. solution, 50 cc. each of the acid and alcohol are mixed together and then added to 900 cc. of water.

this method to prevent damage to cargo of vessel by fire; or the sulphur may be burned in a special furnace, the sulphur dioxide being distributed by a power fan. This method is peculiarly applicable to cargo vessels.

Liquefied sulphur dioxide may be used for disinfection in place of sulphur dioxide generated as above, it being borne in mind that this process will require 2 pounds of the liquefied gas for each pound of sulphur as indicated in the above paragraphs.

Sulphur dioxide is especially applicable to the holds of vessels, or to freight cars and apartments that may be tightly closed and which do not contain objects injured by the gas. Sulphur dioxide bleaches fabrics or materials dyed with vegetable or aniline dyes. It destroys linen or cotton goods by rotting the fiber through the agency of the acids formed. It injures most metals.

Formaldehyde-gas.—Formaldehyde-gas is effective if applied by one of the methods given below. Formaldehyde-gas has the advantage as a disinfectant that it does not injure fabrics or most colors. It is not poisonous to the higher forms of animal life. It fails to kill vermin such as rats, mice, roaches, bed-bugs, etc. The method is not applicable to the holds of large vessels. Formaldehyde is applicable to the disinfection of rooms, clothing, and fabrics, but should not be depended upon for bedding, upholstered furniture, and the like, when deep penetration is required.

Many formaldehyde solutions do not contain 40 per cent. of formaldehyde, and all are apt to deteriorate with time. It is therefore necessary to use a quantity in excess of the amount prescribed in these regulations, unless the solution has been recently analyzed.

The following methods of evolving the gas may be used:

(*a*) Autoclave under pressure, 3 to 12 hours' exposure.

(*b*) Lamp or generator, 6 to 18 hours' exposure.

(*c*) Spraying, 12 to 24 hours' exposure.

(*d*) Formaldehyde and dry heat in partial vacuum, 1 hour's exposure.

(*e*) Chemical, as formalin-permanganate method of Russel, or formalin-aluminum sulphate-lime method of Walker, 6 to 18 hours' exposure.

The minimum number of hours' exposure, as given above, applies to empty rooms of tight construction containing smooth, hard surfaces; the maximum number of hours' exposure applying in all cases to textiles and other articles of a similar kind requiring more or less penetration.

(*a*) Autoclave under pressure: This method has considerable penetrating power when applied as detailed below. Rooms or apartments need no special preparation beyond the ordinary closing of doors and windows. Pasting, caulking, or chinking of ordinary cracks and crevices is not necessary. The doors of lockers and closets and the drawers of bureaus should be opened. In this apparatus use formalin (40 per cent.), with the addition of a neutral salt, such as calcium chloride (20 per cent.). The gas must be evolved under a pressure not less than 45 pounds. After the gas is separated from its watery solution the pressure may be allowed to fall and steam projected into the compartment to supply the necessary moisture. Use not less than 10 ounces of formalin per 1000 cubic feet, and keep the room closed for three to twelve hours after the completion of the process. For large rooms the gas must be introduced at several points as far apart as possible. It is applicable to the disinfection of clothing and fabrics suspended loosely in such a manner that every article is freely accessible to the gas from all directions.

(*b*) Lamp or generator: This method requires an apparatus producing formaldehyde by a partial oxidation of wood alcohol, and in using it the room or apartment should be rendered as tight as practicable. Oxidize 24 ounces of wood alcohol per 1000 cubic feet, and keep the room closed from six to eighteen hours, in accordance with the provisions in a previous paragraph. This method leaves little or no odor. When applied to clothing and textiles, the articles should be suspended in a tight room and so

disposed as to permit free access of the gas. (See also previous paragraph.) The wood alcohol should be of 95 per cent. strength, and should not contain more than 5 per cent. of acetone.

(*c*) Spraying: The formalin (40 per cent.) should be sprayed on sheets suspended in the room in such a manner that the solution remains in small drops on the sheet. Spray not less than 10 ounces of formalin (40 per cent.) for each 1000 cubic feet. Used in this way a sheet will hold about 5 ounces without dripping or the drops running together. The room must be very tightly sealed in disinfecting with this process, and kept closed not less than twelve hours. The method is limited to rooms or apartments not exceeding 2000 cubic feet. The formalin may also be sprayed upon the walls, floors, and objects in the rooms.

This method is markedly interfered with by, and is not to be relied on at, low temperatures, say below 72° F. At 43.5° F., very little formaldehyde is liberated, the formaldehyde being polymerized on the sheets.

(*d*) Formaldehyde with dry heat in partial vacuum: This method has superior penetrating powers and is especially applicable to clothing and baggage. The requirements of this method are (1) dry heat of 60° C. sustained for one hour; (2) a vacuum of 15 inches; (3) formaldehyde evolved from a mixture of formalin with a neutral salt, in an autoclave under pressure, using not less than 30 ounces of formalin (40 per cent.) for 1000 cubic feet; and (4) a total exposure, under these combined conditions, of one hour.[1]

(*e*) Chemical, as (1) Formalin-permanganate method. When formalin is poured over crystals of permanganate of potash, a vigorous reaction takes place and a large quantity of formaldehyde-gas is liberated. Reaction is over in a short time, five minutes, and if a proper proportion of substances is used, the residue is almost dry.

[1] It should be noted that formaldehyde disinfection is more efficient in warm, moist, or still weather than in cold, dry, or windy weather.

The proportion is 2 pints of formalin to 1 pound of permanganate of potash. One pint of formalin for 1000 cubic feet of space should be used if the temperature is 60° F. or less; a less amount may be used for higher temperatures, but not less than 10 ounces per 1000 cubic feet. This method is extremely efficient on account of the rapidity with which the gas is liberated, but the danger of fire should be guarded against, as the formaldehyde-gas being in a comparatively dry state, is inflammable in the presence of a light, such as lighted matches, lamps, etc.

(2) Formalin-aluminum sulphate-lime method. Add 1 part sulphate of aluminum to 2 parts of hot water. One part of this solution is added to 2 parts of formalin (both by volume). One part of this second solution is poured on 2 parts of unslaked lime (quick lime), broken into small particles. The process of liberation of formaldehyde-gas is completed in about twenty minutes. This method is not as efficient as the previous one, as less than half the amount of formaldehyde-gas is yielded from the same amount of formalin.

Two pints of formalin per 1000 cubic feet of space should be used, if the temperature is 60° F. or less.

The Quarantine Regulations also include (in Amendment No. 6, issued January 16, 1923) instructions for the preparation of cyanogen chloride gas mixture for fumigation to destroy rats and other rodents, mosquitoes, lice, fleas, and other vermin on shipboard or elsewhere. A copy of these instructions, which are omitted here because of their length and because they cannot well be condensed, may be had on application to the Surgeon General of the U. S. Public Health Service, Washington, D. C.

There are, of course, other needs for disinfection than those indicated in the foregoing discussion, and numerous other substances or agents that may be used as efficient disinfectants. For example, many articles of commerce that are brought from countries where various infectious diseases are pandemic or quite common, or that are inherently likely to be infected, such as rags, hides, wool, hair,

etc., need to be thoroughly disinfected before they may be handled by workers here in safety. Likewise, there are industrial enterprises or processes in which disinfection or its equivalent, sterilization, should be an essential and requisite feature, this being especially true with regard to apparatus, materials, etc., concerned in the preparation and conservation of foodstuffs.

As for other disinfectants, there are many not already mentioned that are of value in special processes or conditions, and new ones are being brought into use or are discovered as occasion or need for them arises. Thus, Dr. H. F. Smyth[1] has recently suggested a method of using a combination of iodine and tetrachloride of carbon for the disinfection of hides and the prevention of anthrax infection that is apparently more satisfactory and efficient than any yet devised for the purpose. The same process can be used for the disinfection of furs or of other articles that have been exposed to infection of other diseases and that might be harmed by the usual methods of disinfection. So with other examples that might be mentioned.

The important point, however, is that we have already discovered that we can control and eliminate the causes of many affections that hitherto took heavy toll from the peoples of the world, and have found some of the means for doing so, with the added assurance that we shall have others as we need them. Disinfection is only one phase of the functions of sanitation, but an important one that should be fully appreciated by all who desire to lessen disease and death in the world.

In the foregoing chapter the author is much indebted to A. C. Abbott's Hygiene of Transmissible Diseases, and Rosenau's Preventive Medicine and Hygiene for authoritative and up-to-date information as to the value of the agents and methods of infection, and the reader is referred to these works for an abundance of detail which the limits of the present volume do not permit.

[1] Am. Jour. Hyg., May., 1923, pp. 224-237.

CHAPTER XIII.

QUARANTINE.

QUARANTINE may be described as the methods and measures imposed by a government—local, State, or national—to prevent the introduction of infectious disease into the country or from one locality to another. Although the term in itself is misleading, being derived from the Italian *quarante* (forty), and signifying the period of detention of the first Venetian quarantines, it is now generally taken to indicate the entire routine of inspection, disinfection, and detention, without regard to the length of time involved.

While all civilized nations have from the earliest times recognized the importance of separating those afflicted with epidemic disease from the well, the development of the idea and practise of quarantine has necessarily been consequent upon the growth of commerce; and while there has been isolation for leprosy for unknown ages, the first quarantine enactments, in our meaning of the term, were put in force in Venice about the beginning of the fifteenth century as a barrier to both the black and the Egyptian plague. Then it was realized that epidemic diseases were transmitted by those attacked, a bureau of health and a lazaretto were established, the effects of those who died of the plague were destroyed, and the period of detention of incoming vessels, passengers, and cargoes were fixed at *forty* days, the idea being that this period was in itself more or less mystic and salutary.

As time went on and the plague spread over the whole of Europe, the number of lazarettos was largely increased, especially in the eighteenth century. Of these, the one at Marseilles became the most noted, not only because it

was located at one of the most important ports of the Mediterranean, but because of its excellent care and management. Thanks to the increased efficacy of quarantine and other sanitary regulations as the knowledge concerning them developed, the plague rapidly subsided soon after the beginning of the last century, and interest in it was supplanted by that in relation to the frequent epidemics of cholera and yellow fever that began to alarm the civilized world; and it is to prevent the ingress of these latter diseases, together with leprosy, smallpox, typhus fever, and plague, that the present quarantine regulations are in the main devised.

With the knowledge already gained regarding the nature and causes of infectious diseases, their periods of incubation, etc., it is at once evident that it will be neither necessary nor wise to fix upon a prolonged and arbitrary time during which vessels or passengers must be detained in quarantine. All that is needed is that the proper inspecting officers shall be satisfied that there is no danger of infection entering the country, and, where any detention is necessary, it is only for so long as will suffice for the disinfection of the vessel, cargo, and passengers' effects, and to cover the period of incubation of the suspected disease.

The present quarantine laws of the United States, and the latest regulations of the Treasury Department based upon them, are especially designed to afford the greatest possible protection to the country against the importation of disease with the least possible detention of incoming vessels and passengers. An important innovation that facilitates both these ends has been the establishment of an American quarantine in foreign lands, as it were, viz., the inspection and, if necessary, detention and disinfection by officers of this government of all vessels, passengers, and cargoes leaving a foreign port for any port of the United States. This undoubtedly greatly diminishes the danger of the introduction of any infectious disease; but in addition, there is that section of the law that provides that the

President, whenever the conditions of affairs seem to warrant it, "shall have power to prohibit, in whole or in part, the introduction of persons and property from such countries or places as he shall designate and for such period of time as he may deem necessary."

Accordingly, every vessel clearing from a foreign port for this country must obtain from the United States consular officer of the port, or from the medical officer appointed for the purpose, a bill of health, "setting forth the sanitary history and condition of said vessel, and that it has in all respects complied with the rules and regulations in such cases prescribed for securing the best sanitary condition of the said vessel, its cargo, passengers, and crew." Before signing the bill of health the consular or medical officer must be satisfied that the conditions certified to therein are true, and must inspect "all vessels from ports at which cholera, yellow fever, or plague in men or rodents prevail, or at which smallpox or typhus fever prevails in epidemic form," and "all vessels carrying steerage passengers." Moreover the vessel must be clean in all parts, especially the hold, forecastle and steerage, and loose dunnage in unladened apartments shall be so arranged as to prevent harborage of rodents before stowing cargo or receiving passengers; and all parts liable to have been infected by any communicable disease must be disinfected before the bill of health is issued.

"At ports where cholera prevails special care should be taken to prevent the water- and food-supply from being infected. The drinking-water, unless of known purity, should be boiled and the food thoroughly cooked and protected against contamination by flies, etc. Where yellow fever prevails, precautions should be taken to prevent the introduction of mosquitoes, aedes (stegomyia) calopus on board the vessel. At ports or places suspected of plague infection in rodents every precaution must be taken to prevent rats, mice and fleas from getting aboard."

"So far as possible, passengers should avoid embarking at a port where quarantinable disease prevails, and com-

munication between the vessel and shore should be reduced to a minimum."

The regulations also indicate what kind of cargo, coming from or through infected districts, may or may not be shipped, and what kinds must invariably be disinfected under any circumstances.

As to the passengers, while they are divided into two classes, cabin and steerage, no person suffering from plague, leprosy, cholera, smallpox, yellow or typhus fever, anthrax, scarlet fever, measles, diphtheria, poliomyelitis (infantile paralysis), influenza, chicken-pox or cerebrospinal meningitis should be allowed to ship. Steerage passengers and members of the crew who have been exposed to smallpox must be vaccinated before embarking unless they can show proof of immunity by former attack or by satisfactory vaccination within one year. If the passengers or any of the crew have been exposed to typhus fever infection, they may not embark until twelve days, and for plague, seven days, after such exposure, while steerage passengers and sailors from cholera-infected districts must be detained for five days in an environment known to be free from any source of infection. Passengers and sailors, who, in the opinion of the inspecting officer, have been definitely exposed to the infection of yellow fever (*i. e.*, as from a house or locality known to be infected), should not be allowed to embark for six days after said exposure. No alien who is a leper should be allowed to embark for the United States.

The baggage of passengers or crew exposed to infection or from infected ports should be inspected and, if necessary, disinfected and, in the case of plague or typhus fever, treated to destroy vermin.

The same rules as to detention and disinfection are to be applied to those coming from places where the plague, yellow fever, or smallpox is prevalent in an epidemic form, and if one of these diseases or cholera breaks out in the detention barracks, there must be a repetition of the previous isolation, disinfection, etc., dating from the

removal of the last case. Cabin passengers from cholera or other infected ports or districts should produce satisfactory evidence as to their exact place of abode during the five days immediately preceding embarkation, and if there is any reason for the belief that any one of these or his baggage has been infected, such passenger is to be detained under medical inspection a sufficient time to cover the period of incubation since the last exposure, and his baggage is to be disinfected.

Every steerage passenger must also have an inspection-card, stamped by the consular or medical officer, giving name and last permanent residence of passenger, and of ship and port with date of departure, etc.; and all baggage of passengers must have a label bearing the seal or stamp of the United States consular or medical officer, the name of port and of the vessel carrying the baggage, and the statement and date of inspection or disinfection.

It is evident that if these regulations at foreign ports, together with those required at sea—viz., rigorous cleanliness and free ventilation of the vessel, daily inspection by the ship's physician, isolation of the sick, disinfection of their clothing, bedding and excreta, destruction of mosquitoes and vermin, etc.—be properly observed, there can be but little chance of the germs of quarantinable disease gaining entrance to our country; and, since the duration of the voyage will in most cases exceed the period of incubation of most of the contagious diseases, if none of these manifest themselves on shipboard at sea there will be no need for any detention at the port of entry beyond that which the inspecting officer stationed there requires for the performance of his duties, viz., to inspect the vessel, bill of health, crew and passengers, and their lists and manifests, the ship physician's clinical record of all cases treated, and, when necessary, the ship's log.

This inspection service is to be maintained at every domestic port throughout the year, and is in force not only with respect to all vessels from foreign ports, but also

regarding any vessel with sickness on board, vessels from domestic ports where cholera or yellow fever prevails, or where smallpox or typhus fever prevails in epidemic form, vessels from foreign ports carrying passengers having entered a port of the United States without complete discharge of passengers or cargo, and vessels having been treated at national quarantine stations that are located a considerable distance from the port of entry of said vessels. Moreover, the duties of the inspecting officer above stated are only the required minimum standard, and such other regulations may be added by legal State or local authorities as may, for special reasons, be necessary.

If the inspecting or health officer is satisfied that the vessel is not infected and all the foregoing requirements have been complied with, he gives his certificate, to be delivered to the collector of customs of the port, and no vessel is permitted to land any of its passengers or cargo unless it have this certificate, together with the bill of health, etc., from the port of departure, as evidence that the regulations have been properly observed.

On the other hand, if vessels arrive under the following conditions they are to be remanded by the authority of the Secretary of the Treasury to the nearest national or other quarantine station where proper accommodations and appliances are provided for the necessary disinfection and treatment of the vessel, passengers, and cargo; and only after treatment and after obtaining a certificate from the proper officer that the vessel, cargo, and passengers are each and all free from infectious disease and from danger of conveying the same, can a vessel be admitted to entry to the ports named in the certificate.

The conditions under which arriving vessels are to be placed in quarantine are these: "(*a*) With quarantinable disease on board or having had such disease on board during the voyage," the quarantinable disease for the purposes of these regulations being cholera, plague, yellow fever, smallpox, typhus fever, leprosy and anthrax. (*b*)

Any vessel which the quarantine officer considers infected with quarantinable disease. (*c*) A vessel arriving at a port south of the southern boundary of Virginia in the season of active quarantine (April 1 to November 1) from a port infected or suspected of infection with yellow fever. (*d*) Vessels arriving at ports north of this line and south of the southern border of Maryland, between May 15 and October 1, if from a port infected or suspected of infection with yellow fever. (*e*) In the case of vessels arriving at a northern port without sickness on board from ports where yellow fever prevails, the personnel shall be detained under observation at quarantine to complete six days from the port of departure. (*f*) Tow-boats and other vessels having had communication with vessels subjected to quarantine shall themselves be quarantined if they have been exposed to infection."[1]

Recent regulations have been made to include aircraft under the same requirements as vessels traversing the water as regards the securing the necessary bills of health from foreign ports, undergoing inspection, being granted pratique, etc.

"At a fully equipped maritime quarantine station there should be adequate provision for boarding and inspection, apparatus for mechanical cleansing of vessels, apparatus for disinfection by steam, by sulphur, by formaldehyde, by disinfecting solutions or any other method prescribed in these regulations; also a clinical laboratory, hospitals for contagious and doubtful cases, a steam laundry, detention barracks for suspects, bathing facilities, a crematory, a sufficient supply of good water and a proper system for the disposal of sewage."[1]

When a vessel is remanded to quarantine by the inspecting officers at a port of entry, its treatment and that of its cargo and passengers will depend largely upon the disease with which it is infected, being more severe if the latter is cholera or yellow fever. In case of infection by

[1] U. S. Quarantine Regulations, June, 1920.

either of these diseases the vessel is at once sent to the anchorage, and must remain there until the passengers have been discharged and the vessel purified, and in any case there must be no direct communication allowed between quarantine or a vessel in quarantine and any person or place outside, except under supervision of the quarantine officer.

The following are taken from the revised edition of the U. S. Quarantine Laws and Regulations of June, 1920: "All persons on vessels upon which cholera has appeared during the voyage shall upon arrival at quarantine be detained until it has been determined by bacteriological examination that they are free from cholera vibrios. Persons in detention who are proven by bacteriological examination (performed not less than twenty-four hours after removal from exposure to infection in cholera case or carrier) to be free from cholera organisms may be discharged from quarantine without further detention. In lieu of bacteriological examination (and then only when it is impracticable) persons exposed to infection in cholera case or carrier shall be detained in quarantine five days after being isolated from such case or carrier. If a case clinically diagnosed as cholera has occurred on voyage, or if bacteriological examination should reveal the presence of infection in any person on board, such infected person or persons should be removed and isolated. All contacts should be segregated in small groups, and no material capable of conveying infection shall be removed from the ship.

"Fruits and vegetables from an infected ship that are ordinarily consumed in an uncooked state shall be destroyed or rendered harmless by cooking. The food served to persons in quarantine, unless from a source known to be free from cholera infection, shall be cooked. The water supply of a vessel detained in quarantine on account of cholera infection, unless determined by bacteriological examination to be free from cholera organisms or *Bacilli coli* shall be sterilized. Otherwise it shall be discharged

after disinfection. The dejecta of all persons in quarantine on account of cholera shall be disinfected before final disposition, and special precautions shall be exercised in order to prevent the contamination of food or water supply or the spread of the infection through the agency of flies or other insects. Personal effects contaminated by dejecta from a cholera case or carrier shall be disinfected. Any part of a ship that has been contaminated by dejecta from a cholera case or carrier shall be washed down with a solution of bichloride or carbolic acid. Carriers or recovered cases shall not be released from quarantine detention until three bacteriological tests performed on consecutive days shall be negative.

"A vessel aboard which a case of yellow fever has occurred at any time during the voyage shall be treated as follows: (*a*) Careful visual and thermometric inspection of all persons. (*b*) The sick are to be immediately disembarked, protected by netting against the access of stegomyia mosquitoes, and transferred to a place of isolation. (*c*) Other persons should be disembarked, if possible, and detained under observation for six days, dating from the day of last possible exposure. (*d*) Persons under observation presenting an elevation of temperature above 37.6° C. shall be isolated in a screened apartment. (*e*) The ship shall be moored if possible at least 200 meters from the inhabited shore. (*f*) The ship shall be fumigated for the destruction of mosquitoes before the discharge of cargo, if possible. If a fumigation be not possible before the discharge of the cargo, the discharge of the cargo shall be under the supervision of the quarantine officer, and may be permitted as follows: By (1) the employment of immune persons for discharging the cargo; or (2) if non-immunes be employed, they shall be kept under observation during the discharging of the cargo and for six days, to date from the last day of exposure on board.

"Ships on which plague has occurred in men or rodents shall be detained in quarantine, the sick, if any, shall be

removed and isolated, and the destruction of rats shall be effected as soon as practicable. A plague-infected ship shall be fumigated simultaneously in all parts for the destruction of rats, including those that may be within articles of cargo, and other precautions shall in the meantime be observed to prevent the escape of rats from the ship. All rodents destroyed on vessels at quarantine shall, when practicable, be bacteriologically examined. All persons sick of plague shall be detained in quarantine until well, but no detention of healthy contacts is contemplated (except in the pneumonic type of the disease) other than is incidental to treatment of vessels or cargo. If pneumonic plague has occurred on board ship during the voyage, the sick shall be removed and isolated and all crew and passengers that have been exposed to the infection shall be detained in quarantine for a period of seven days, or, at the discretion of the quarantine officer, until their secretions shall be proven to be free from *Bacilli pestis*. The quarantine officer before granting pratique to a vessel that has been detained in quarantine on account of plague infection shall assure himself that the vessel is free from rats and vermin.

"Vessels on which typhus infection has occurred shall be detained in quarantine and the sick, if any, removed and isolated. The clothing, personal effects and baggage of those infected and of those not demonstrably vermin-free shall be treated for the destruction of vermin. All persons found to be vermin (louse) infested shall be treated for destruction of lice. All passengers and crew that have been exposed to the infection shall be detained under observation for a period of twelve days from last exposure to infection. Those of the personnel that are demonstrably free from vermin, and have not been exposed to the infection, may be released without detention or disinfection of baggage. Vessels on which typhus has appeared shall be detained and fumigated for destruction of vermin. Sulphur dioxide and hydrocyanic acid gas are effective agents for the destruction of lice when used in proper strength and exposure.

"Vessels arriving with smallpox on board or having had smallpox on board during the voyage shall be treated as follows: (*a*) The sick shall be removed and detained until recovered. (*b*) All persons who in the opinion of the quarantine officer have been exposed to the infection shall be vaccinated, unless protected by a previous attack of smallpox, and detained in quarantine until the vaccination is protective against said exposure, or, if they refuse vaccination, detained in quarantine for fourteen days after last exposure to the infection. Those persons that have not been exposed to the infection shall be released. All personal effects of passengers and crew that have been exposed to infection shall be disinfected. All compartments that have been exposed to the liability of infection shall be disinfected.

"Vessels arriving in quarantine with leprosy on board shall not be granted pratique until the leper and his baggage has been removed from the vessel to the quarantine station. No alien leper shall be permitted to land, and to this end the case shall be certified as a leper and reported to the nearest commissioner of immigration. If the leper be a citizen of the United States, the case shall promptly be reported to the Surgeon-General for action."

The disinfection of the holds of vessels is to be by mechanical cleansing, by an acid bichloride of mercury solution (1 to 800) applied under pressure, and by sulphurous acid-gas (10 per cent. per volume strength) for from twenty-four to forty-eight hours. All ballast must be discharged or disinfected before the disinfection of the hold, and all solid ballast must be disinfected before being discharged into fresh water. The steerage and forecastle are to be disinfected by live steam, if possible, for at least half an hour, and, if not, by sulphur dioxide and bichloride solution, as was the hold. Baggage, bedding, carpets, etc., are to be removed with caution and to be disinfected by steam or by boiling, and, finally, all woodwork of the vessel is to be thoroughly cleansed mechanically and then washed with an acid bichloride of mercury solution (1 to 1000).

The following *Rules* for the application of disinfectants in quarantine work were issued as part of the quarantine regulations of the United States Government on October 20, 1910:

APPLICATION OF DISINFECTANTS IN QUARANTINE WORK.

The holds of iron vessels, empty, shall be disinfected by either:

(*a*) Sulphur dioxide generated by burning sulphur, 5 pounds per 1000 cubic feet of air space, or liberated from 10 pounds of liquid sulphur dioxide, sufficient moisture being present in both cases; time of exposure, twenty-four hours.

(*b*) Washing with a solution of bichloride of mercury, 1 to 1000.

Holds of wooden vessels, empty, shall be disinfected by:

(*a*) Sulphur dioxide in the manner prescribed above, followed by:

(*b*) Washing with a solution of bichloride of mercury.

Holds of cargo vessels, when cargo cannot be removed, shall be disinfected in so far as possible by sulphur dioxide, not less than 4 per cent. per volume strength, and where possible this should be generated from a furnace to minimize danger of fire in cargo.

Living apartments, cabins, and forecastles of vessels shall be disinfected by one or more of the following methods:

(*a*) Sulphur dioxide; the destructive action of the gas on property being borne in mind.

(*b*) Formaldehyde-gas.

(*c*) Washing with solution of bichloride of mercury, 1 to 1000, or 5 per cent. solution of formalin, or 5 per cent. solution of carbolic acid, preference being given to carbolic

acid for application to polished woods, bright metals, and other objects injured by metallic salts.

The forecastle, steerage, and other living apartments in bad sanitary condition must be disinfected by method (*a*) followed by method (*c*).

Mattresses, pillows, and heavy fabrics are to be disinfected by:

(*a*) Boiling.

(*b*) Flowing steam, *i. e.*, steam not under pressure.

(*c*) Steam under pressure.

(*d*) Steam in a special apparatus with vacuum attachment.

Clothing, fabrics, textiles, curtains, hangings, etc., may be treated by either of the above methods from (*a*) to (*d*) inclusive, as circumstances may demand, or by formaldehyde-gas or sulphur dioxide where the article is of a character which will not be damaged by sulphur dioxide.

Articles injured by steam, such as leather, furs, skins, rubber, trunks, valises, hats and caps, bound books, silks, and fine woolens should not be disinfected by steam. Such articles should be disinfected by formaldehyde-gas or by any of the agents allowed in these regulations which may be applicable thereto. Those which will be injured by wetting should be disinfected by a gaseous agent.

Clothing, textiles, and baggage, clean and in good condition, but suspected of infection, can be efficiently and least injuriously disinfected by formaldehyde-gas, generated by one of the methods previously described.

Textiles which are soiled with the discharges of the sick or presumably are deeply infected, must be disinfected by:

(*a*) Boiling.

(*b*) Steam.

(*c*) Immersion in one of the germicidal solutions.

Cooking and eating utensils are always to be disinfected by immersion in boiling water or by steam.

As to the passengers and others who have been isolated in groups, they are to be inspected twice daily by the physician and remain under his constant surveillance,

and can have no communication with anyone in a different group or outside of quarantine, except through the quarantine officer. The water-supply and food-supply are to be strictly guarded, and are issued to each group separately. The latter is to be simple in character and abundant in quantity, but no fruit is to be permitted. Strict cleanliness is to be enjoined, disinfection wherever necessary, and, in case quarantinable disease appears in any group, the sick will be immediately removed to the hospital, and the rest of the group bathed and their effects disinfected, and all of them removed to other quarters, if possible. None are to leave quarantine until the end of the incubation period of the disease in question, dating from the last exposure to infection and the final disinfection of such effects as were taken to barracks; and no convalescent may leave quarantine until a bacteriological examination shows him to be free from infection.

BORDER QUARANTINE.

"When necessary, travelers arriving at Canadian or Mexican ports destined for the United States shall be inspected at the Canadian or Mexican port of arrival by the United States consular or medical officer, and be subjected to the same sanitary restrictions as are called for by the rules and regulations applicable at foreign ports. Where not otherwise specifically stated, the rules and regulations for maritime quarantine shall be applied at stations on the Canadian and Mexican frontiers; and the methods of disinfection shall be those prescribed in these regulations. If any person be found suffering from a quarantinable disease, or be presumably infected, he shall be denied entry or shall be kept under quarantine observation so long as danger of conveying the infection exists. Any baggage or other effects believed to be infected shall be refused entry unless disinfected in accordance with these regulations. No common carrier which is infected, or suspected of being infected, shall

be allowed to enter the United States until after such measures have been taken as will render it safe."[1]

The regulations also provide that persons coming from localities where cholera, yellow fever, typhus fever or smallpox are prevailing shall not be allowed to enter the country until they have been proven safe or immune by bacteriological examination, detention, disinfection or vaccination as may be advisable in each case, and persons shall not enter the United States from countries where any quarantinable diseases are prevalent except at designated points of entry and after an inspection by a quarantine officer and undergoing the specified treatment.

There is also provision for the inspection of State or local quarantines from time to time by the Supervising Surgeon-General of the U. S. Public Health Service, or by any officer of that service detailed by him; and for the observance at all quarantines of such additional rules and regulations as may from time to time be promulgated by him.

INLAND QUARANTINE.

Under this heading may be considered the means that may be employed to prevent an epidemic extending from one locality or district to another, although the principle and aims are practically the same as those of maritime quarantines, viz., to define certain boundaries beyond which no person or thing capable of carrying infection may pass, and to establish certain points of ingress or egress on these boundaries where there may be the necessary detention, inspection, disinfection, etc.

The *sanitary cordon* "consists of a line of guards, military or civil, thrown around a district or locality, either to protect the same from the surrounding country when infected, or to protect the surrounding country from the infected district or locality." "It is not intended to bottle up all the people who are caught within an infected district, but, on the contrary, is intended as a means of

[1] U. S. Quarantine Laws and Regulations, 1920.

exit to those who will not carry with them contagious diseases to the people beyond."[1] It may be single or double; in the latter case the inner line closely encircles the well-defined infected locality, and the outer line the whole suspected territory. This latter may be removed as soon as it is evident that the space between it and the inner line is not infected. To be efficient the cordon must be so guarded that, even though it be many miles in length, no unauthorized person may pass through it, while at certain places upon it *camps of probation* or *detention* must be established, where all persons coming from the infected locality may be kept under observation for a time equal to the period of incubation of the disease in question. These camps of probation or detention are to be distinguished from the *camps of refuge*, which were first suggested by Surgeon-General Woodward in 1878, and which are "simple residence camps established to receive the population of an infected community when it has been determined to depopulate the infected district."

At these camps of detention provision must be made for inspecting every person and disinfecting all baggage before entering camp, for isolating the occupants and housing and feeding them in the most comfortable and sanitary manner during the detention, for inspections twice or thrice daily, for the isolation and care of the sick in hospitals at a safe distance from camp, and for the issuance of a certificate granting "free pratique" when the period of detention is over.

A notable instance of the sanitary cordon was that about the city of Brownsville, Texas, and along the Rio Grande, in 1882; and of a detention camp, that at Camp Perry, Florida, in 1888.

In addition to these measures it may be necessary or advisable to establish a *railroad quarantine*, as follows: "At certain convenient points, which will be the only

[1] Rohé's Hygiene, "Quarantine."

points of egress by rail from the infected district, an inspection service and disinfecting station are to be maintained throughout the epidemic. Here all the baggage and freight are to be properly disinfected and all passengers are to be examined by the official inspectors; if the latter are from the infected locality, or have not a certificate from some recognized health officer as to where they have been for the previous days corresponding to the incubative period of the disease, they are to be at once remanded to the nearest camp of probation, there to undergo the necessary detention. Moreover, it may seem advisable to prevent any passenger cars going beyond the infected district, and to disinfect all freight and baggage cars that do so."

Local and House Quarantine.—There may also be local or house quarantines established by municipal boards of health or other authorities to prevent not only the family or attendants of the sick from mingling with the rest of the community, but also to keep injudicious outsiders from spreading the infection through unwise visitations. And though such isolation may appear at times a hardship to certain individuals and to be unduly severe, one should not forget the great cost to all concerned of epidemics once inaugurated, nor that it is only by such stringent measures that we shall be able to eradicate the infectious maladies from our communities. Good citizenship requires that every one should do all in his power to protect the public welfare, even at some personal sacrifice, and that all measures designed to eliminate common enemies should be consistently supported rather than evaded or contravened.

CHAPTER XIV.

THE REMOVAL AND DISPOSAL OF SEWAGE.

The waste from dwellings is of three kinds: house-sweepings and the ashes from fires; the waste from kitchens, scraps of food, etc., commonly known as garbage, and sewage, the most important, consisting as it does of the solid and liquid excreta of the body together with waste water from wash-tubs, bath-tubs, kitchens, laundries, etc.

Ashes alone have little effect upon the health, except that they absorb moisture readily, and if allowed to accumulate in a cellar may do much to keep it damp and mouldy. For the same reason, if they be mixed with refuse vegetable matters, putrefaction is favored and noxious emanations given off. The dust from ash heaps may also be carried into the house and largely increase the solid impurities of the air therein. Consequently, ashes should be frequently and regularly removed from the premises.

Kitchen refuse or garbage readily decays, and if allowed to remain in the vicinity of the house may pollute both the air and soil about it; but inasmuch as it has some value as a food for animals, there is usually no difficulty in the smaller communities in having it removed by scavengers without expense or delay. Care must be had, however, that this is done properly and that all receptacles are kept in as cleanly a condition as possible. Most large cities now find it safer to collect and dispose of the garbage at the expense of the municipality, rather than to allow private individuals to keep for its consumption large number of animals within or near the city limits. Even though the

former plan be apparently the more expensive at first because of the cost of the plant, experience shows that this garbage may and should be treated in properly arranged reduction apparatus at convenient locations with some financial return and without annoyance to the residents of the vicinity, thus saving the expense and time necessary for conveying the refuse beyond the municipal limits and obviating the offensive nuisance of large piggeries which must be maintained in relative proximity to the city. The author is reliably informed that the sale of grease, etc., from its garbage returns a small profit to Philadelphia over the cost of its collection and the operation of the reduction plants.

The kind of waste to which we give the name *sewage* is, however, of more importance to sanitarians, since it is always a possible factor in the production of disease, and since it presents the greater difficulties in respect to its removal from dwellings and the ultimate disposal of it.

In addition to the substances already named and which usually come from dwelling-houses, sewage may contain the liquid excreta from stables, the refuse from factories of all kinds, the drainage from polluted soils, and the excess of rain-water not taken up by evaporation or retained in the soil. Its composition must therefore be always complex and variable, but there will be practically always present in it sodium chloride, ammonia, carbon monoxide and dioxide, hydrogen and ammonium sulphide, fetid and decomposing organic matter, and myriads of bacteria. Fresh sewage will not be so offensive to the senses as that in which putrefaction has commenced, nor will the gases arising from it be so dangerous to health. Frankland has shown that "solid or liquid matter is not likely to be scattered into the air from the sewage itself by any agitation it is likely to undergo until gas begins to be generated in it;" and it is really doubtful whether the air of a properly constructed and well-ventilated sewer can be shown to contain a harmful excess of injurious gases and organisms. However, it

is essential that sewage should be removed from the premises of a dwelling as soon as possible after its production and before decomposition begins.

When the above-mentioned constituents of sewage are to be disposed of collectively, the *water-carriage* system is usually the best. Although the *pneumatic* system (wherein air-tight pipes extend from the dwellings, etc., to reservoirs from which the air is periodically exhausted and the sewage thus drawn into them) would seem to be advantageous where the topographical conditions do not permit of natural drainage, it is always subject to the danger of breaks occurring and destroying the action, and seems to have been practically successful in but few instances.

A modification of the pneumatic system which seems to be more successful and practical is the *Shone* or *ejector* system. In this the sewage is conducted by gravity through suitable drains to convenient ejector stations or tanks, whence it is forced by means of compressed air to the irrigation fields or other places of ultimate disposal.

On the other hand, where house refuse only is to be considered, and where the waste-water can be kept from the other parts of the sewage, or where a scanty water-supply, the physical conditions, or the cost of constructing the necessary sewers prevent the use of the water-carriage method, recourse should be had to the *pail* or *earth closet* system or to the septic tank or biologic method of disposal. The use of primitive privy-vaults or cesspools is most insanitary and dangerous, and should be condemned in almost every instance. Where the necessity for one of the latter seems imperative, it should be made absolutely water-tight, so that none of the contents may escape to pollute the surrounding soil and soil-air or to contaminate the ground-water in the neighborhood. Moreover, the pits should be properly ventilated and should be cleaned out regularly and often, which may be done without offence by some form of odorless excavating apparatus, such as is now commonly used.

The daily addition of a solution of chlorinated lime or milk of lime or of sulphate of iron, to the extent of about two quarts for each person using the cesspool, will do much in the way of checking bacterial growth, even though it does not actually disinfect the contents, and will largely prevent the offensive odors of putrefaction from such accumulations. It should be noted that the contents of such a vault, or of a simple pit in the earth, undergo putrefaction rather than natural decomposition, if no antiseptic be used, because of the lack of sufficient oxygen supply and of the adjunct action of the nitrifying bacteria which are found only in the uppermost layers of the soil.

It is also probable that many disease germs, particularly those of diphtheria or typhoid fever, will survive and multiply better in the contents of such a vault than in sewage or refuse treated by the methods to be hereafter described.

In the *pail* system the more solid waste matters, and especially human excreta, are collected in a suitable pail or tub, which, holding only a limited amount, must of necessity be removed and emptied regularly and often. If the outbuildings used for this purpose be kept clean and properly ventilated, such a system will be both economical and healthful.

Advantage may here be taken of the great deodorizing, nitrifying, and oxidizing power of fine, dry earth, and various forms of *earth-closets* have been devised to be used in conjunction with the pail system. If a quantity of dry, sifted earth, in bulk about twice that of the dejecta, is thrown upon the latter after using the closet, they will be rendered inodorous and inoffensive. For this purpose loam and clay are best, though sifted ashes may be used with almost as good results, but sand or gravel will not be as efficient as the loam or ashes. Moreover, owing probably to the action of the nitrifying bacteria in the earth, all traces of the peculiar nature of the organic compounds are quickly destroyed, and the mixture soon

becomes practically nothing but humus and inoffensive to the senses.

Harrington[1] says of peat used for this purpose that it "has not only remarkable power of absorption, but also very marked bactericidal properties. It will absorb and retain from nine to eighteen times its weight of water, it acts as a deodorant in the same manner as charcoal, and it retains ammonia in apparently unchanged condition. Experiment has shown that neither the typhoid nor cholera organisms can retain their vitality in contact with peat longer than a very few hours, and the same is true of many other varieties of bacteria."

The pail or earth-closet must, of course, be separate and apart from the dwelling, as it is impossible to have the same means of keeping the gaseous emanations and effluvia out of the house as with the water-carriage system; and it is also important that the liquid house-slops, wash-water, etc., be kept separate from the fecal waste, which should be kept as dry as possible to lessen putrefaction and the production of disagreeable odors and gases. Nor should this liquid waste be allowed to soak into and pollute the soil about the house. It should be collected in a water-tight reservoir, whence it can be removed at frequent intervals, or, better yet, carried by suitable drains to a kitchen garden or other land at a proper distance from the house, and be there disposed of by irrigation or sub-irrigation.

As one can readily see, the pail or earth-closet system is especially well adapted to isolated houses and small communities, where each householder can take care that the necessary details are properly attended to, and where, as is likely, there is not a general water-supply, or where the expense of constructing the necessary sewers would be too great.

But even in cities as large as Manchester, England, "where four-fifths of the people are obliged to have earth-closets," the system is said to have proved entirely advantageous and practicable.

[1] Practical Hygiene, 1st edition, p. 470.

Where there is a common and general supply of water throughout the house or to a number of houses there must be some provision for carrying off the waste-water, and as this latter will probably have become polluted in its use, it will be advantageous to employ it to remove the other sewage. In fact, where the conditions are favorable the water-carriage system will usually be found the best of all, because it is more nearly automatic and depends least on human interference and efficiency.

The necessary apparatus comprises, on the one hand, that which belongs to the building and its premises, viz.: the house fixtures, pipes, and drains; and, on the other, the common or public sewers which receive the sewage from the house-drains and convey it to its place of ultimate disposal.

SEWAGE-PLUMBING AND HOUSE-DRAINAGE.

The essence of any good system for the removal of sewage from a dwelling or building is simplicity. Therefore, inasmuch as it has been stated that sewage should always be removed from the premises as soon as possible after its production and before fermentation or putrefaction begins in it, it is evident that in such a system we should have for our object and should provide for: "(1) The speediest possible removal from the house to the public sewer of excretal and other refuse by means of water. (2) The prevention of the deposit of foul matter in any part of the drainage system and of percolation into the soil of polluting liquids. (3) The establishment of a current of air through every part of the soil-drains and pipes, in order to disperse any foul gases that may form and to allow them to escape with safety into the open air. (4) The prevention of any entry of air from soil-pipes, drains, and waste-pipes into the house. (5) The exclusion of the air of the common sewer from the house-drains and the house; the last being, perhaps, the most important, as the air of the public sewer may at any time con-

tain the active germs of specific disease."[1] Some modern authorities, however, would omit this last requirement on the ground that the air of the street sewer is no worse than that in the house-drains and soil-pipes of dwellings and that the latter, because of their number and frequency, afford one of the best means of ventilating the common sewer.

The attainment of the above requirements is to be secured in the manner to be described. The *soil-pipe* is that which receives the sewage from water-closets and, usually, from the waste-pipes of other fixtures, such as bath-tubs, wash-stands, sinks, etc., and which connects them with the *house-drain;* the latter is the conduit connecting the soil-pipe with the sewer. *Waste-pipes* convey the contents of wash-stands and other fixtures to the soil-pipes or to a branch of the house-drain. (See Fig. 102.)

The soil-pipe is usually located almost entirely within the house, although, were it not for the danger of its contents freezing, it would be better to have it fastened to the wall outside. It is made of cast or wrought iron, should be at least four inches in diameter, should convey the sewage as directly as possible from the fixtures to the house-drain, and must extend unobstructed from the latter to several feet above the roof, ending where winds and currents from high walls and chimneys will not interfere with its free ventilation. Every branch of the soil-pipe more than eight feet in length, or to which two or more water-closets are connected, should also be extended above the roof, or else be extended and connected to the main soil-pipe above the highest fixture connected therewith, as there must be no closed ends wherein foul or stagnant air may collect. All joints must be absolutely air-tight, and the pipe must be so secured that any vibration or settling of the building will not be likely to destroy its continuity. In new buildings, especially, it would be well if

[1] L. C. Parkes, Hygiene and Public Health, 2d edition, p. 139.

all soil-pipes were exposed or else covered in with panels easily removable at any time to permit of inspection or

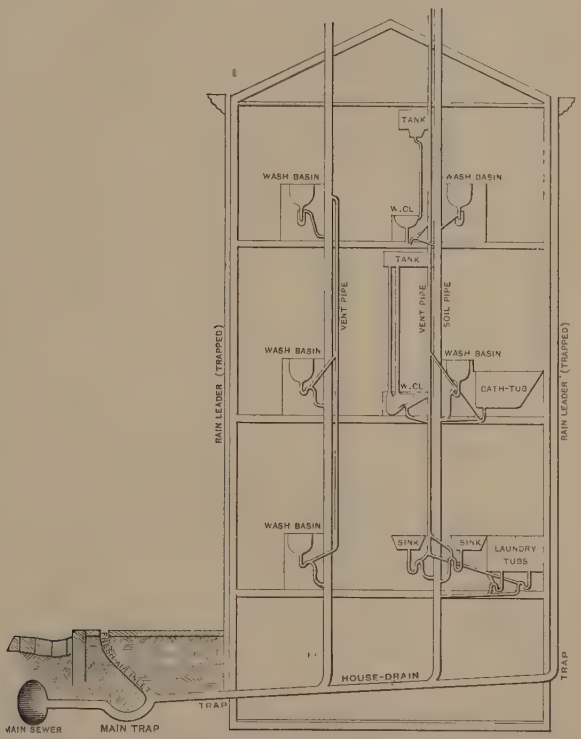


FIG. 102.—Illustrating sewage-plumbing of a house. The traps of the rain leaders at their junctions with the house drain have been accidentally omitted.

repairs. Any hidden pipes or those difficult of access should be of extra heavy materials, and extra care should be given

to the joints and supports. The soil-pipe and house-drain should both be as smooth as possible interiorly, and in the construction they must be carefully inspected to prevent any of the material used in caulking or cementing the joints from projecting within to obstruct the free flow of sewage.

Outside of the house the house-drain may be of iron or of glazed and impervious earthenware, but no earthen pipe should be permitted within five feet of a foundation wall, and where any part of the house-drain is within the building it should be of iron and securely fastened to the

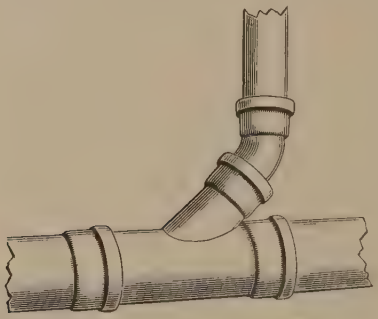


FIG. 103.—Method of connecting soil-pipe with house-drain.

foundation-wall above the cellar floor. The connection between it and any soil-pipe should be by means of a rounded elbow, and not by an abrupt right angle. (Fig. 103.) The house-drain should not be less than four nor more than ten inches in diameter, should be laid on a firm foundation, should have air-tight joints, and should have a slope toward the sewer of at least one-half inch to the foot.

If a house-drain empty into a sewer of the "combined" system, there should be a trap just before its junction with the sewer to prevent the passage of sewer-air back

into the house (Fig. 102) unless it is planned to use such house connections to ventilate the sewer, and there must also be an inlet for fresh air on the house side of this trap, so that there may be a constant current through the house-drain and soil-pipes to the exit above the roof, and the air in the soil-pipes thus kept from becoming foul and stagnant. But if the house-drain empties into a sewer of the "separate" system, there need be no trap between the drain and sewer, because the air in the latter will probably be better than that in a "combined" sewer and because there is otherwise practically no adequate ventilation of the "separate" sewer. However, the fresh-air inlet between sewer and house-drain is always advisable, as it tends further to assist ventilation.

A house-drain should not empty into a cesspool unless it is absolutely necessary, and in such case the cesspool must be well ventilated and also separated from the drain by a fresh-air inlet and trap, just as when the drain empties into a combined sewer.[1] Nor should any cesspool empty into a sewer.

Where rain-water conductors empty into house-drains or sewers, they should be separated from the latter by traps having a seal of not less than five inches, to prevent sewer-air passing up through them to the vicinity of windows, etc. So, also, all waste-pipes, gutters, and other pipes opening into house-drains should be trapped.

In the house all water-closets and other fixtures should be as near the soil-pipe as possible that there may be no long stretches of foul waste-pipe underneath the floors, and all connections with the soil-pipe should be made at an acute angle that the discharge into the latter may not interfere with its free ventilation. Each fixture must be separately trapped, and the trap must be located as near its fixture as possible. There must be no connection

[1] The "septic tank" hereafter described must not be confused with the cesspool mentioned here, as it is permissible to connect the house-drain directly to a properly constructed septic tank, for reasons that are made apparent in the description of the latter.

between a fixture and the soil-pipe or house-drain which is not trapped.

A little reflection will show that by observing the above rules of construction provision will have been made for each of the five specified requirements of the system, and the air in the soil-pipes will be almost as pure as that of the house itself. The absorption of foul gases by the water in the house-traps and their subsequent dispersion into the atmosphere of the house will also be almost impossible. But there must always be free communication between the air inlet into the house-drain and the outlets from and at the top of the soil-pipes; otherwise

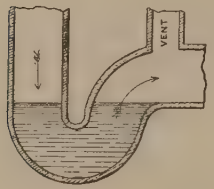


FIG. 104

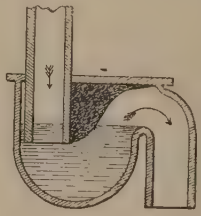


FIG. 105

FIGS. 104 and 105.—These illustrations show how a uniform caliber prevents the accumulation of dirt in a trap, and how angles and corners favor such accumulations. (Gerhard.)

the air in the soil-pipe cannot be changed and foul gases will accumulate which, by their pressure, would tend to force themselves into the house whenever an opportunity occurred, and might even overcome the seal of some of the traps.

Sewage-traps are "appliances placed between house conveniences (fixtures) and soil-pipes and drains or sewers, to prevent sewer-gas gaining an entrance into the house." Many traps are too complicated. The simpler a trap the better, provided it have sufficient seal. The seal of a trap is the depth of water or the mechanical appliance which prevents the back-flow of gas. Mechanical appli-

ances are liable to become clogged and not to fit tightly, thus allowing the passage of sewer-air; they also tend to check the free onward flow of the sewage, thus favoring deposition in, and preventing, the cleansing of the trap.

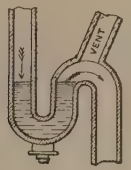


FIG. 106.—S or siphon trap, with opening for ventilation pipe. (Gerhard.)

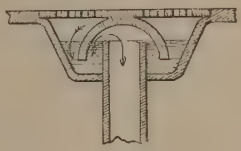


FIG. 107.—Bell trap. (Gerhard.)

The S or siphon trap is as simple as any, is of uniform diameter throughout, has no corners or projections to catch dirt, and is thoroughly cleansed by each fair flow of water through it. The value of a trap does not depend so much on the amount of water it contains as on the depth or strength of the seal. On account of evaporation

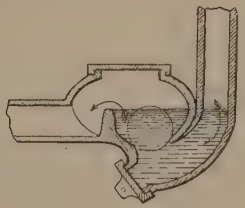


FIG. 108.—Cudell's trap. (Gerhard.)

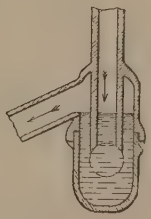


FIG. 109.—Bower's trap. (Gerhard.)

the water-seal of a trap may become lessened or destroyed unless the fixture to which it is attached be in frequent use; it is therefore advisable to have as few fixtures of any kind in the house as the comfort or convenience of

the inmates will allow. So, also, if a house is to be unoccupied for a time, it is well to cover the water in the traps with oil or glycerin to prevent evaporation of the former. Leakage or capillary action, the latter caused by accumulations of hair, thread, etc., in the trap, may likewise lower the water so that sewer-gas may pass through from the soil-pipe.

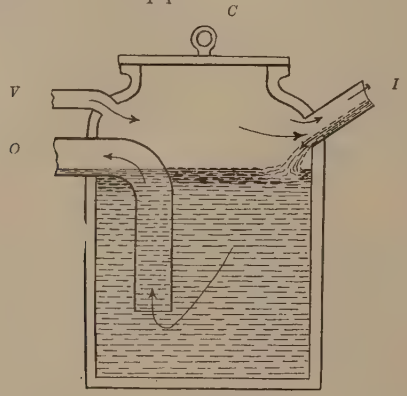


FIG. 110.—Grease trap. *C*, cover; *I*, inlet; *V*, vent; *O*, outlet. (Harrington.)

Lastly, the seal of a trap may be broken by siphonage, either by a strong rush of water through it from its own fixture, or by a rush down the soil-pipe from a fixture higher up, and this is especially liable to occur if the trap be some distance from the soil-pipe, or if the fixtures above discharge a large amount of water at once. To prevent this, openings are frequently made at the top of the traps on the side next the waste-pipe or soil-pipe and connected with vent-pipes, which should open into the soil-pipe above the entrance of the waste-pipe from the highest fixture, or be continued separately into the out-door air. (See Fig. 110.) But this increases the expense, and, as the vent-pipes, to be efficient, must be almost two inches

in diameter, they also favor evaporation from the trap. If the trap is properly constructed, if the soil-pipe is of suitable size and height, and if the fixtures be placed as near the soil-pipe as possible, there will be practically

FIG. 111.—A modern bath-room. (Courtesy of the Standard Sanitary Manufacturing Co.)

little danger of siphonage occurring. It is also said that if the waste-pipe be connected with the soil-pipe by a somewhat divergent opening, siphonage will be less likely to occur.

All waste-pipes, soil-pipes, and house-drains, should be tested before use by closing all openings and forcing in air to a pressure of at least thirty pounds to the square inch. Leaks may also be detected by plugging the lower openings and filling the pipes with water, or by pouring an ounce of oil of peppermint into the highest fixture and quickly following this with several gallons of hot water, the heat volatilizing the oil, whose odor escapes at every opening in the pipes unprotected by a trap or water-seal. The heat imparted by the hot water will also help to trace out hidden soil-pipes.

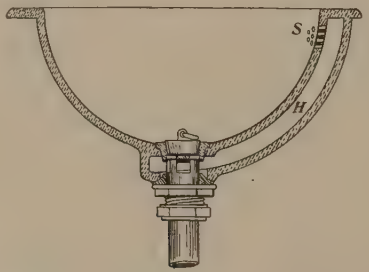


FIG. 112.—Old-fashioned wash-basin with overflow horn discharging beneath plug. (Harrington.)

All fixtures should be exposed to the free ventilation of air underneath and about them, and water-closets and wash-stands should not be closed in with carpentry work. (See Fig. 111.) Traps should also, if possible, be where they may be opened and inspected at any time. Under each closed-in fixture, if there must be such, there should be a drip-safe to catch any leakage or overflow of water, but the pipes, if any, leading from these should never empty into waste-pipes or soil-pipes; they should lead preferably into the open air and not to the cellar, as the cellar-air, which is usually impure, thus gains access to the house. Even if these drip-safe pipes are trapped

and open into the soil-pipe, the water in the trap is replenished so rarely that evaporation soon destroys the seal and allows the air to pass from the soil-pipe into the house.

The overflow pipe of old-fashioned wash-stands and bath-tubs is objectionable, as it collects dirt of all kinds, soap, epithelium, etc., and it is almost impossible to clean it. Beside, it will often be found opening into the waste-

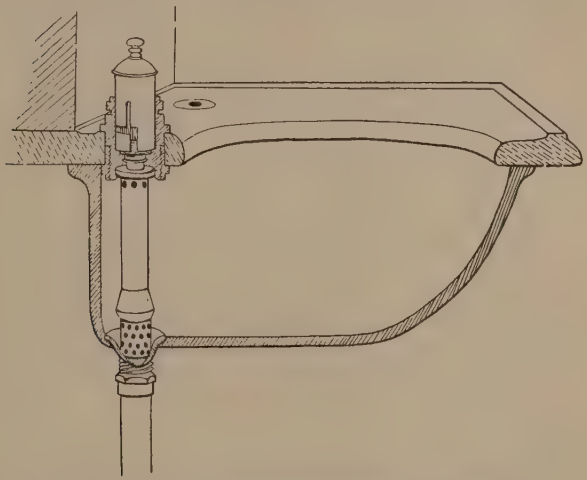


FIG. 113.—Improved stand-pipe overflow. (Harrington.)

pipe *below* the trap, thus allowing the free passage of sewer-air into the room. When new fixtures are being put in they should preferably be such as make use of the stand-pipe or equally safe principle in the stoppers and that have no separate or concealed overflow pipe or outlet (Figs. 112 and 113).

Water-closets.—The requisites for a good water-closet are: that it does not allow the escape of sewer-air from the

soil-pipes into the house; that it is thoroughly and easily cleaned each time after use; that there are no hidden parts in which filth can collect, or which cannot be readily cleaned; that the flushing or washing out of the closet be done in such a way that dirt or spray be not thrown into the air of the room; that there be sufficient water-supply to wash out the bowl and trap each time and to refill them to the proper level; that the trap itself is not siphoned or left empty by a discharge of water from this or another fixture.

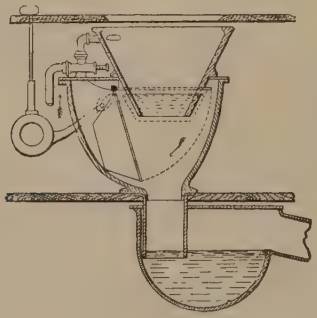


FIG. 114.—Pan closet. (Gerhard.)

Of the different kinds of water-closets the pan and the valve closets are among the oldest and the worst, and should not be used anywhere. They consist of a receiving bowl, the bottom of which opens into a swinging pan or is closed by a valve. The pan or valve and the lower part of the receiving bowl are enclosed in another bowl, the container, connected with the soil-pipe and trap. The depth of water in the receiving bowl in pan closets is regulated by the depth of the pan, and in valve closets by the location of an overflow outlet. In both kinds the contents of the receiving bowl are discharged into the container by the tipping of the pan or valve, and consequently the sides of the con-

tainer, as well as the under side of the pan or valve, soon become thickly coated with filth. This, being hidden, accumulates, decomposes, and contaminates the air in the container, which air is of necessity discharged into the room as often as it is displaced by the contents of the receiving bowl. In valve closets the overflow-pipe from the receiver furnishes an additional way by which the foul air may pass from the container into the atmosphere of the room. It needs no argument to show that these closets are probably inimical to health.

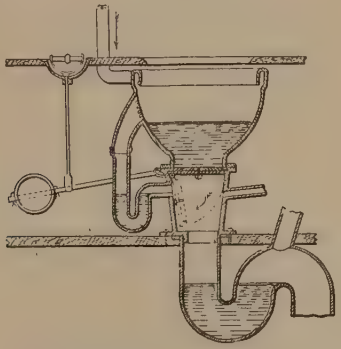


FIG. 115.—Valve closet. (Gerhard.)

Plug or plunger closets are those in which the outlet above the trap is stoppered by a plunger, this being usually in a chamber at the side of the receiving bowl, and are almost as objectionable as pan or valve closets, modern plumbing wisely discarding all three. The bowl and side chamber holding a considerable quantity of water, the trap is well flushed out each time of use; but the side chamber and plunger, being hidden and not easily cleaned, soon become coated with filth and dangerous to health, as there is nothing to prevent the air from passing from this chamber into the room. Moreover, the plug

may not close the opening completely, thus allowing a continual waste of water. A trapped overflow-pipe in the plunger keeps the closet from overflowing.

Hopper closets consist simply of a bowl connected below with an ordinary trap, and, as there is nothing to get out of order, this kind is theoretically one of the best. The objection to long hoppers is that dirt is apt to stick to the sides and become offensive, but this can be prevented if it is so arranged that water begins to flow down the sides as soon as the closet is put to use, thus preventing adhesion.

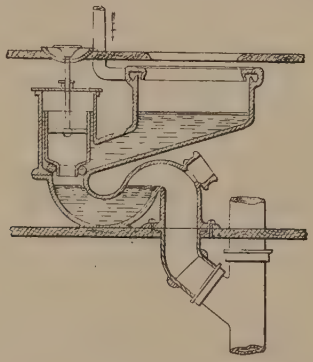


FIG. 116.—Plug or plunger closet. (Gerhard.)

Short hoppers have not this objection, as the feces fall directly into the water in the bowl and are carried out through the traps as the bowl is flushed. All water-closets should have a flushing rim encircling the top, so that all sides of the bowl may be washed down and cleansed each time the closet is used

Wash-out closets retain considerable water in the bowl, and are emptied by a strong flush of water from the flushing rim. They are simple, do not readily get out of order, and have been much in favor up to the present time, but siphon closets are now tending to supplant

them. As they are a modification of the short-hopper closet, so is the siphon closet a modification of the wash-out variety.

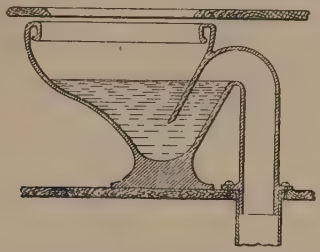


FIG. 117.—Short-hopper closet. (Gerhard.)

In the siphon closet the contents of the bowl and trap are lifted out by siphonic action, and then the bowl and trap are refilled, as in the case of wash-out closets, by an after-flush. In the Dececo closet—a siphon closet—use

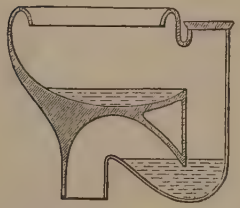


FIG. 118.—Wash-out water-closet. (Parkes.) This bowl is too shallow.

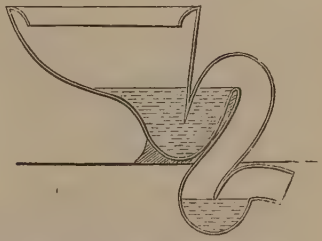


FIG. 119.—Dececo siphon closet. (Parkes.)

is made of the principle involved in the Field flush-tank.

Hopper, wash-out, and siphon closets should be supplied from water-closet tanks, which should give a certain and sufficient volume of water with only a short pull

on the chain or pressure on the rod or knob. The bowl and trap should also be automatically refilled from the tank after use.

Water-closets should not be connected directly with the water-supply pipes of the house, as air from the closets may be sucked into them at times when the water-supply is cut off, and the water afterward contaminated by it. But this is difficult to avoid in pan, valve, or plug closets, and is another serious objection to their use.

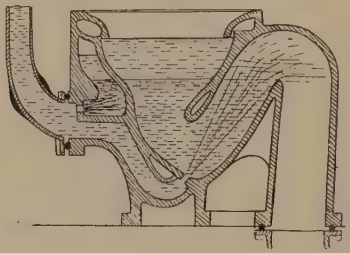


FIG. 120.—Sanitas siphon closet. (Harrington.)

Vent-pipes from the bowl and seat of water-closets, if used, must be large, and must not open into the soil-pipe, but into the open-air; they must not open near a window nor any place from which air is taken into the house, but may open into a flue which is constantly heated, as a kitchen chimney, or may themselves be heated and have a current maintained in them by a small lamp or gas-jet. In this way the room in which a water-closet is located may be effectively ventilated. But it is rare to find such vent pipes now as a part of modern plumbing.

Water-closets should never be placed in dark closets nor in bed-rooms or living-rooms, but should always be in separate rooms that have free communication with the open air by means of a large window or by a ventilating shaft of at least four square feet sectional area throughout

its length. It is also advisable that bed-rooms should not communicate directly with bath-rooms, etc., containing water-closets, unless there is every assurance that the closet and plumbing connected with it are first-class in every particular.

It will not be out of place to suggest in this connection that apparatus for household conveniences, such as wash-stands, bath-tubs, water-closets, kitchen sinks, etc., which satisfies every practical sanitary requirement can now be had at prices that are quite reasonable when the necessary care and scientific experience in construction are taken into consideration. Much advance has been in the reducing of the number of parts in an article, some being now made in a single piece, thus lessening or eliminating the crevices that would collect and hold dangerous filth; likewise concealed overflow pipes and corners and depressions difficult to clean have been done away with; and a third gain has been in the substitution of solid vitrified or enameled metal ware for articles that were made of comparatively soft substance and with a glazed surface that was liable to crack and thus permit the absorption of foul matters and possibly harmful organisms. That these advantages have also been accompanied by an advance in esthetic appearances is well demonstrated by the illustration on page 463, or by what may be seen in almost any well-equipped modern dwelling.

SEWERS.

These are the conduits provided to receive and convey the contents of house-drains and other drains to the place of final disposal or discharge. They may be of either of two kinds—*combined* or *separate*. Sewers of the first class, which have heretofore been most commonly used in this country, are constructed to carry off all kinds of sewage, the waste liquids, etc., from factories, street-washings, and the surplus rain-water of the district drained by them. As this necessitates a size and capacity

sufficient to receive the greatest probable rainfall upon the area drained in addition to the other sewage, it is evident that the depth of the usual daily volume of the latter in the sewer will be so shallow and the current so sluggish as greatly to favor the settling of the solid and semisolid constituents, the obstruction of the sewers, and the development of bacteria and sewer-gas. To

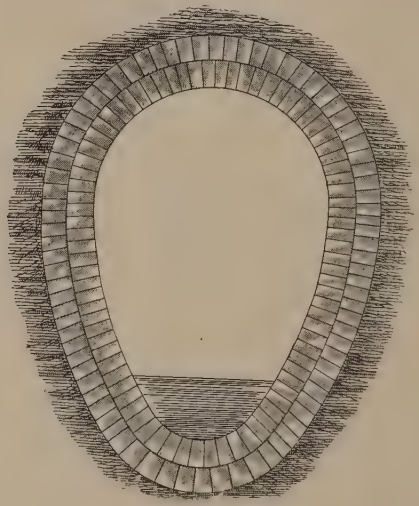


Fig. 121.—Section of ovoid sewer of "combined" system.

obviate these faults and to insure a more rapid flow by keeping the depth of sewage as great as possible, the smaller conduits, at least, are generally made ovoid in section, the smaller end, of course, being downward. Combined sewers are not only more expensive to construct and to keep in repair than those of the separate system, but greater care must be had to see that they are at all times properly ventilated. The main advantage claimed

for them is that the expense of constructing separate conduits for factory wastes, street-washings, and the excess of rain-water is avoided; but this is a doubtful one both in respect to economy and sanitation.

The ventilation of sewers of this kind is usually sufficiently provided for by the inlets for street-washings and rain-water located at street-corners, and by manholes but if these are not close enough together to keep the sewer atmosphere constantly changing and reasonably pure, other ventilation openings should be made. Heretofore the practice has been to exclude the air of combined sewers from house connections by means of the traps already described, but of late there is a tendency to utilize such house connections as efficient ventilators of the sewers because of their number and frequency, and also because it is realized that the air of a properly constructed and maintained sewer is quite as pure as that in the house connection.

Only the sewage proper from dwellings, and occasionally from small factories, is admitted to the sewers of the *separate* system, the rain-waters, surface-waters and soil-waters being removed by other drains or channels. The advantages of this system, which is now indorsed by almost all sanitarians, are that the volume of sewage to be carried is comparatively small and constant, and that it can be calculated very approximately from the daily water-supply and population; that the cost of construction is much less than that of sewers of the combined system, and that, while it is available and satisfactory for large cities, it is the only one that small communities would consider or can afford; that the sewage is more concentrated and uniform in composition, and can thus be better utilized as a fertilizer or disposed of in whatever manner may be most sanitary and advantageous; that the sewers, having smaller peripheries and smoother walls, are more frequently and effectually flushed, and that they are more completely ventilated and altogether better suited to the work to be performed. The disadvantages of sewers

of this class are that a community must have two sets of drains, one for sewage and the other for rain, street, and factory waters, and that after a protracted dry season the street-washings, etc., may be very foul; but these are outweighed by the advantages mentioned above.

"No sewer of this system should be more than six inches in diameter until it and its branches have accumulated a sufficient flow at the hour of greatest use to fill this size half-full, because the use of a larger size is wasteful and because ventilation becomes less complete as the size increases. The size should be increased gradually

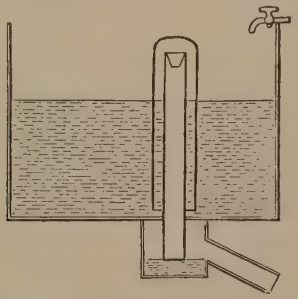


FIG. 122.—Field's annular siphon flush-tank. (Parkes.)

and only so rapidly as is necessary by the filling of the sewer half-full at the hour of greatest flow; and the upper end of each branch sewer should be provided with an automatic flush-tank (Fig. 122) of sufficient capacity to secure the thorough daily cleansing of so much of the conduit as from the limited flow is liable to deposit solid matters by the way."

There should ordinarily be no traps between house-drains and sewers of the separate system, since, having no rain-water inlets, the latter would otherwise have no openings for ventilation. Moreover, since the "separate" sewers are so regularly and thoroughly flushed, the air in

them is not likely to be impure, and there is not as much reason for excluding it from the house-drains, etc., as there is regarding the air from "combined" sewers. The junction of house-drains with sewers of the separate system should be by divergent openings, so that the air may pass freely into the drain as the sewage empties into the sewer.

Should one desire, however, to separate his house-drain from the public sewer by means of a trap, and thus prevent the ingress of sewer-air into his premises, the ventilation of the sewer can be secured by providing a vent-pipe between the trap and the sewer. But in no case must the inlet-pipe for air on the other side of the trap, between it and the house, be omitted; nor should the two air-pipes be so near together that air from the former will be likely to be drawn into the latter.

All sewers should be laid on a good foundation with sufficient fall to give at least a velocity of two feet per second to the flow. If made of brick, they should be laid in a mortar made of cement and sharp sand, and all sewers should be as smooth as possible inside to prevent the arrest of particles of sewage. Sewers of the combined system should not be pervious to the soil-water, as the liquid sewage is just as apt to pass from them to the soil and to pollute it dangerously as the soil-water is to pass into the sewers. But the rain-water drains of the separate system may also be employed to drain the subsoil.

DISPOSAL OF SEWAGE.

The ultimate disposal of sewage is a matter of considerable importance which commonly does not receive the attention it deserves. The method frequently employed in this country of discharging the sewage into a running stream is reprehensible, because the natural purification of a water thus contaminated must always be slow and more or less uncertain, and because the risk to those using the polluted water must be a constantly increasing one.

Where the district drained and supplied by the stream is a sparsely settled one, and where the volume of fresh or running water is very large in proportion to the quantity of pollution it receives, the objections to the disposal of sewage in this way may seem to be theoretical rather than practical; but as the population increases and the ratio of pure water to filth decreases beyond certain limits, the question becomes more serious and pertinent. It is said that to dilute safely the sewage of 1000 persons requires from 2,000,000 to 4,000,000 gallons of unpolluted water per day; this, of course, not destroying the disease germs nor eliminating the danger of their multiplication.

Other methods of sewage disposal resemble closely those already described for the purification of water, in that they make use of straining and subsidence, chemical and biological treatment, and filtration. In order that sewage may "lose permanently its power for evil" and not be a source of nuisance either to the community from which it comes or to others, it is necessary that it undergo certain changes or treatment after it reaches the end of the sewer system and before being discharged into a stream or body of water which, perforce, must practically always be the ultimate destination of the water content (over 98 per cent.) of all sewage. Such change or treatment consists essentially in the oxidation and mineralization of the putrescible organic constituents of the sewage into the simplest end-products, viz., carbonic and nitric acids and their salts, and water; the elimination or destruction of pathogenic organisms, and, incidentally or where necessary, the removal of insoluble inorganic matter or of certain harmful or objectionable factory wastes, acids, alkalies, etc.

What method will be best suited and most satisfactory for a given locality can only be determined by a consideration of all the conditions and factors involved, including frequently careful preliminary experimental treatment over a reasonable period of time. The installa-

PLATE IV

FACTORS IN SEWAGE PURIFICATION BY DILUTION

MAN

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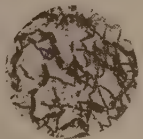
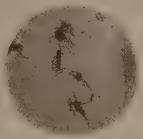


HAVING SPORES



HAVING FLAGELLA

ALGA

PEDIASTRUM

MICRASTERIAS

PROTOZOA

ZOOTHAMNIA

PERIDINIUM

CRUSTACEA

CYCLOPS

NAUPLIUS

FISH

BUREAU OF SURVEYS
DEPARTMENT OF PUBLIC WORKS
CITY OF PHILADELPHIA

AUGUST 1913.

tion of works for the proper conversion of the sewage of a community will relatively involve considerable expense, and it will be difficult or impossible in the near future to secure a change in method, if a wrong or unsatisfactory one be first put in use. Among the methods already successfully employed both in this country and abroad may be mentioned, straining by means of fixed or movable screens, sedimentation, liquefaction by so-called "septic" action, the use of activated sludge, filtration and irrigation. The striking feature is that in almost all of these except sedimentation and mechanical straining, the essential and greater part of the work is done by the living microörganisms normally present in the sewage itself and without the addition of extraneous substances. Two or more of the above methods may be and frequently are combined with much better results than would be possible if only one of them were used.

Straining is accomplished by means of screens of various kinds or by coarse-grained filters made of coke (one-quarter inch), buckwheat coal or the like. The screens may be fixed or movable and be made of rods, wire gauze or perforated plates with openings of various sizes according to the material which it is desired to remove by this method and also according to the subsequent treatment of the sewage. The movable screens bring the collected matter above the surface of the sewage where they are cleaned by brushes, scrapers or an air blast.

The simplest sedimentation treatment is to allow the sewage to flow slowly through a tank, this securing better deposition of the sludge than the alternate filling, and emptying of the settling basin, provided the addition of chemical precipitants is not to be made. Care should be had to secure an even flow through the whole cross-section of the tank above the sludge deposit on the bottom. With a rate of flow about fifty feet per hour and four hours or so for the time of settling, good results may be expected.

The sewage may be collected in large tanks, with the addition of certain chemicals, such as lime, alum, or sulphate

of iron, to increase the precipitation, and the suspended impurities allowed to settle to the bottom of the tanks, whence they can be removed, squeezed partially dry in hydraulic presses, and either disposed of as a fertilizer or cremated. The clear effluent or liquid part of the sewage may be allowed to flow at once from the settling tanks into a convenient watercourse, provided it is there well diluted, or it may better be filtered through an area of porous soil or through prepared filter-beds. If the filtration is properly done, the filtrate will contain nothing harmful, and may be allowed to flow where it will without danger.

Chemical treatment will probably cost from thirty-five to fifty cents or more per annum per individual of the population supplying the sewage, but an even more important question than cost is whether the addition of the chemicals may not interfere with the natural biological processes of purification constantly taking place in most sewage and interfere with the further purification of the effluent. Chemicals that are or have been used as precipitants are lime, lime with sulphate of iron, alum, or alkali waste, sulphate of iron alone, and a combination of alum, charcoal, and clay. The precipitate obtained with the latter makes a fertilizer of some value, but it is not well to count too much upon a financial return from this as a by-product.

The *septic-tank* method of disposal of sewage particularly aims to take advantage of the biological and saprophytic action occurring naturally in all polluted waters. The idea is to favor and not to hinder the purifying bacteria and other agencies by placing the sewage under the conditions most favorable to their growth and action, thus facilitating the conversion of organic matters, both solid and dissolved, into substances entirely harmless and unobjectionable. In other words, advantage is to be taken of the action of both the anaërobic and aërobic saprophytes which abound in all sewage that is not too strongly impregnated with antiseptic chemical wastes from factories or other sources. In the intermittent

filtration and irrigation methods of sewage disposal the service of the anaërobic organisms is practically eliminated because the success of these methods depends largely upon a free and frequent aëration of the filtering material or the soil. On the other hand, the purpose of the septic tank is first to make use of the disintegrating and liquefying action of the anaërobic bacteria upon the undissolved organic matter before subjecting the sewage to the action

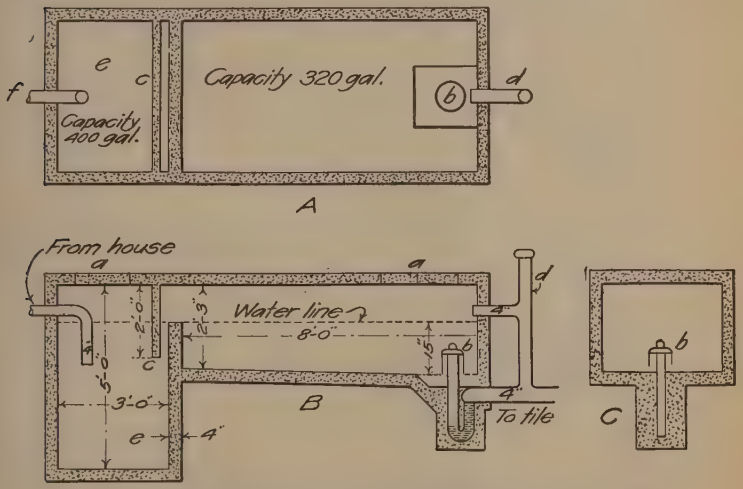


FIG. 123.—Double-chamber septic tank for family of six people, suitable to conditions where outlet fall is difficult to obtain.[1]

of the aërobic bacteria which it contains. Hence it is well to precede either intermittent filtration or irrigation by first passing the sewage through the septic tank. A similar action but not so complete may be had by the preliminary use of a contact filter.

The septic tank for large volumes of sewage should be

[1] Bulletin., U. S. Department of Agriculture.

long and comparatively shallow, but should have such a capacity and cross-section that the sewage will pass through the tank in from six to twelve hours. At the upper end the fresh sewage should enter within a few inches of the bottom of the settling or "grit chamber," which is separated by a partition from the rest of the tank, and in which most of the street sand and other inorganic solids are collected. Thence it goes into the larger space, where the anaërobic bacteria carry on their work.

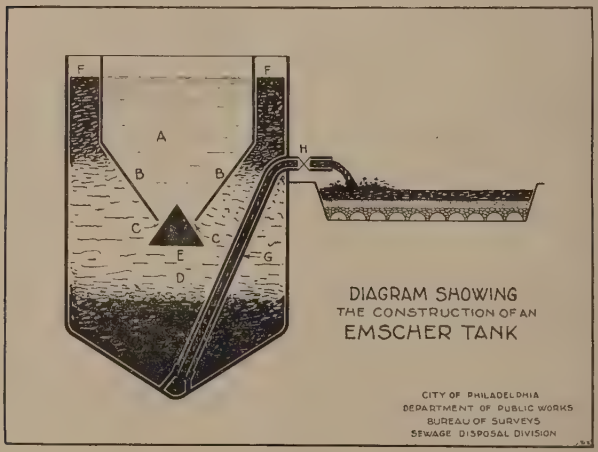


FIG. 124

The tank may be entirely covered in to exclude air and light, for though a thick scum or cake of sludge soon forms on top that would serve this purpose, there is some possibility of it being broken and air admitted by ice, snow, and other causes. However, experience has seemed to show that tanks without other covering than the sludge work fairly well and to give an effluent as good as that from tanks that were covered. As the sewage

passes slowly through the tank the organic matter is decomposed with the evolution of considerable gas that might be collected and used for heating or lighting purposes, if the tank and volume of sewage were large enough to warrant it. An important variation of the septic tank is the so-called "digestion tank." Of these "the best known type is the Imhoff, or Emscher, tank. This is a deep septic tank divided by sloping partitions into an upper and a lower compartment, so arranged that the sewage flows slowly through the upper compartment while the sludge settles through openings in the partition walls into the lower compartment, where digestion takes place. The advantage of this type of septic tank is that the sludge alone is submitted to septic action without allowing the products of decomposition to mix with the flowing sewage above, while more complete digestion improves the character of the sludge from the stand-point of subsequent disposal."[1] This virtue of smaller bulk and quicker drying possessed by the sludge from Emscher tanks is of considerable importance when the volume of sewage to be treated is as great as that furnished by our larger American cities with their abundant water supplies.

The author just quoted also states that septic sedimentation continued from twenty-four to forty-eight hours will remove from 40 to 50 per cent. of suspended matter in weak sewage and from 80 to 85 per cent. in strong sewage.

The table on page 482 prepared by Dr. Rideal indicates the changes in sewage due to biologic action in septic tanks, contact beds, trickling and intermittent filters, etc.

The effluent from a septic tank may be carried into a shallow aërating trough over the sides of which the fluid flows in thin sheets, whence it may be conveyed to intermittent filters or irrigation fields; or it may be distributed through fixed or travelling sprinklers on aërobic or contact beds, or on trickling filters, the object in all being to enable the sewage to be thoroughly and

[1] Rosenau, Preventive Medicine and Hygiene, p. 853.

speedily acted upon by the aërobic bacteria. Irrigation fields for our larger and rapidly growing cities are practically out of the question because of the great area of necessary land and its high cost, and for the same reason intermittent filters may also be inadvisable for cities of the largest size. For it must be remembered that the volume of sewage per capita is very much greater in American than in foreign cities, both because of our overgenerous supplies of water to dwellings and of the

	Substances dealt with.	Characteristic products.
INITIAL.		
Transient aërobic changes by the oxygen of the water supply, rapidly passing to:	Urea, ammonia, and easily decomposable matters	
FIRST STAGE.		
Anaërobic liquefaction and preparation by hydrolysis	Albuminous matters; cellulose and fiber; fats	Soluble nitrogenous compounds and fatty acids; phenol derivatives; gases, ammonia
SECOND STAGE.		
Semi-anaërobic breaking down of the intermediate dissolved bodies	Amido compounds; fatty acids, dissolved residues, phenolic bodies	Ammonia, nitrites, gases.
THIRD STAGE.		
Complete aëration; nitrification	Ammonia and carbonaceous residues	Carbonic acid, water and nitrates.

almost universal use of "combined" sewers, which add the rain-water, factory wastes and street washings to the sewage proper.

Aërobic or contact beds are large water-tight vats or tanks filled with porous materials, such as cinders or coke, etc., from $\frac{1}{8}$ to $\frac{1}{2}$ inch in size, the idea being that there should be as much capacity for the sewage as possible, and at the same time a ready aëration of the mass when the bed is drained, the beds becoming more efficient after being used some time, as they have thus become impregnated with the right kinds of bacteria. When a

contact bed is filled with sewage and allowed to stand there is a rapid deposit of suspended and colloidal matter upon the myriads of surfaces of the porous material of which the filter is constructed, which deposit is rapidly acted upon by the ever present bacteria which increase in number from day to day. This action is partly anaërobic when the bed is filled with sewage, but becomes mainly aërobic as the fluid is drawn off and air refills the interstices of the bed. After filling, the beds are left undis-

FIG. 125.—Trickling or percolating filter, Pennypack Creek Works, Philadelphia.

turbed for a couple of hours, and are then drained, after which they remain empty for from two to four hours, it having been found possible by using automatic filling and emptying valves to repeat the process three or four times daily. It will usually be wise to carry the effluent from the septic tank through at least two of these beds, but if the process is properly accomplished, "by this purification an effluent is obtained which is saturated with dissolved oxygen, which remains entirely inoffensive in smell for an indefinite period in an

incubator at summer heat, and which therefore, when discharged into a water-course, would maintain the respiration of fish, and would never render the water offensive."[1]

"Trickling filters, otherwise called 'sprinkling filters' or 'percolating filters,' consist of beds of porous material such as broken stone, coke or clinkers upon which the sewage is sprinkled and through which it percolates to underdrains laid on a tight floor beneath. The entire bed is arranged with reference to complete aëration throughout, in order that the organic matter of the sewage may become thoroughly oxidized. The suspended matter of the sewage is not permanently retained in the beds, but flakes off at intervals and is carried out in the effluent, which is turbid and requires subsequent clarification. The object of the trickling filter is to change the character of the organic matter so as to render it non-putrescible. The rate of application varies from 500,000 to 2,000,000 gallons per acre daily, one acre of trickling filter serving a population of 10,000 or more. Well-operated sprinkling filters receiving the effluent from plain sedimentation or septic tanks are capable of removing from 85 to 90 per cent. of the suspended matter and from 90 to 95 per cent. of bacteria, yielding an effluent that is non-putrescible."[2] This method is useful when sandy areas of suitable size are not available for intermittent filtration or are too expensive. The subsequent clarification of the effluent from trickling or sprinkling filters may be satisfactorily accomplished by the addition of chlorinated lime and passage through a settling basin of moderate size.

Sewage may also be disposed of by intermittent downward filtration, either through specially constructed filter-beds or a prepared area of soil, and by irrigation or sub-irrigation. "The volume of sewage which may be successfully purified upon a given filter area is inversely proportional to the amount of suspended matters in the

[1] Leffmann, Civic Hygiene, in Vol. V of Cohen's System of Physiologic Therapeutics.

[2] Rosenau, Preventive Medicine and Hygiene, 1st ed., p. 858.

sewage applied. In other words, if the whole or a part of the suspended matters are removed from the sewage by some treatment preliminary to filtration, the filters can be operated at much greater rates and a smaller area will be required for the treatment of a given volume of sewage.[1]"

For sewage, intermittent filtration is superior to the continuous process—in fact, is almost essential, as the interruption in the percolation permits a renewal of the air-supply in the filtering medium or soil, and thus furnishes a sufficient quota of oxygen for the use of the aërobic bacteria and for the oxidation and nitrification of the excessive amount of organic matter in the sewage. With sufficiently frequent intermittence, fine sand, such as is used for building purposes, makes an excellent artificial filter, capable, it is stated, of purifying 50,000 gallons of crude sewage per acre per day and of removing all the solids, much of the dissolved matters, and 99 per cent. of the contained bacteria. Where the crude sewage is allowed to settle or is treated biologically in septic tanks, a much greater quantity of the clarified effluent can be filtered daily, as has been indicated.

By *intermittent soil filtration* we mean "the concentration of sewage at short intervals, on an area of specially chosen porous ground, as *small* as will absorb and cleanse it; not excluding vegetation, but making the produce of secondary importance. The intermittency of application is a *sine qua non* even in suitably constituted soils wherever complete success is aimed at."[2] The land should be levelled and underdrained with tile drains at the depth of five or six feet, and should be divided into four parts, no part to receive sewage for a longer time than that which comprises one-quarter of the daily flow. An acre of properly prepared soil will thus dispose of the crude sewage of 1000 to 2000, or the clarified sewage of 5000 people.

The soil to be used for this purpose, as well as that for

[1] Report of Massachusetts State Board of Health, 1908.
[2] Metropolitan Sewage Commission; see Notter and Firth, p. 546.

irrigation and sub-irrigation, should be porous and loamy; if clay, it should be well broken up and mixed with ashes; sand does not purify sewage well, especially at first, in these methods. The sewage impurities are removed partly by mechanical filtration, but especially by oxidation, the latter being due partly to the air in the interstices of the soil, but chiefly to the aërobic saprophytic bacteria, which rapidly convert the organic impurities into ammonia, nitrates, nitrites, and other simple compounds.

Irrigation means "the distribution of sewage over a large surface of ordinary agricultural ground, having in view a maximum growth of vegetation, consistently with due purification, for the amount of sewage supplied."[1] Sub-irrigation is a modification of this, the sewage being delivered through uncemented drains a few inches beneath the surface of the soil. Unless very porous, the land should be underdrained; it should also be levelled to prevent the sewage flowing off the surface too rapidly. The underdrains need not be nearly so close together, however, as in the intermittent filtration system. The crops raised on irrigation farms are healthful in every respect, and there can be no reasonable objection to their use as food; there would be decided objection, however, to sprinkling the vegetables with sewage water.

For example, an epidemic of typhoid fever in Prague, in 1903, was traced to the use of radishes which had been placed in polluted river water in order to freshen them and improve their appearance for marketing. It is accordingly probable that many cases of this disease of obscure origin may arise in a similar way, since it is by no means uncommon for the "truck" gardeners in the neighborhood of cities to use the contents of privy vaults etc., as fertilizer, and Rullman has shown that typhoid bacilli may live for six months or even a year in human, and more especially in organic filth. Thus celery, banked for bleaching with such a soil, might readily become a

[1] Metropolitan Sewage Commission; see Notter and Firth, p. 547.

carrier of the harmful germs. On the other hand, it is not likely that the latter are carried to and taken up by the rootlets of the plants growing on the sewage farms, for the records of the latter thus far tend to disprove this.

On the large irrigation farms of the city of Berlin, which had a population of about two million, the cost of sewage disposal before the recent war was about covered by the returns from the crops raised upon them. The mortality

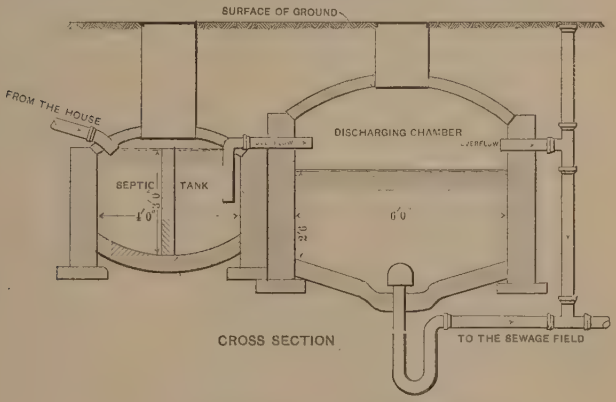


FIG. 126.—Septic tank for private dwelling.

of those employed upon them is very low, and there seems to be no particular tendency to illness that can be attributed to the sewage. It is even said that the employees use with impunity the clear water in the effluent canals for drinking and other purposes. Paris has also adopted the irrigation method, and the sewage of a large portion of the city is treated in this way. The sewage of from 100 to 150 persons per acre may be satisfactorily disposed of by irrigation, Berlin's rate, with an especially favorable soil, being 142 per acre. It is to be especially

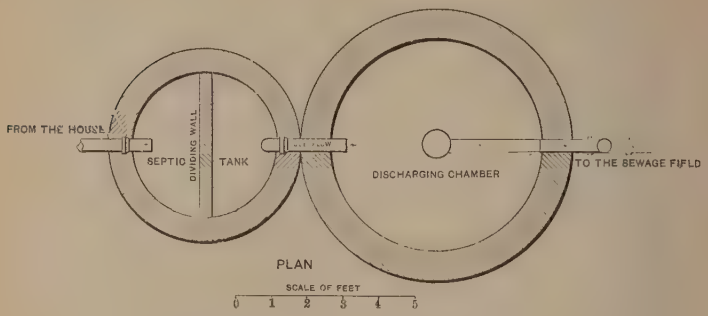


FIG. 127.—Septic tank for private dwelling.

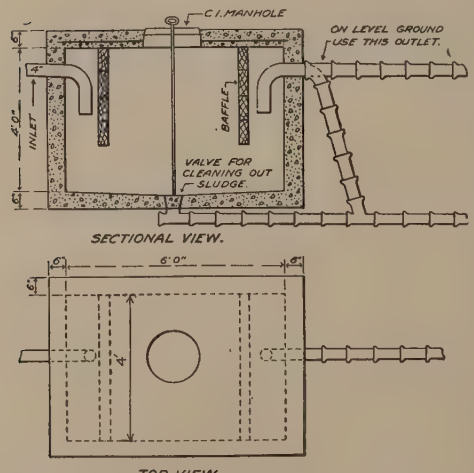


FIG. 128.—Single-chamber septic tank for six people.[1]

[1] U. S. Department of Agriculture, Bulletin on Water Supply, Plumbing, and Sewage Disposal for Country Homes.

recommended for isolated houses, for small communities, or for charitable or other State institutions.

For private suburban or country dwellings, the Illinois State Board of Health have recommended the small septic tank illustrated in Figs. 126 and 127, for which the following description is given.[1]

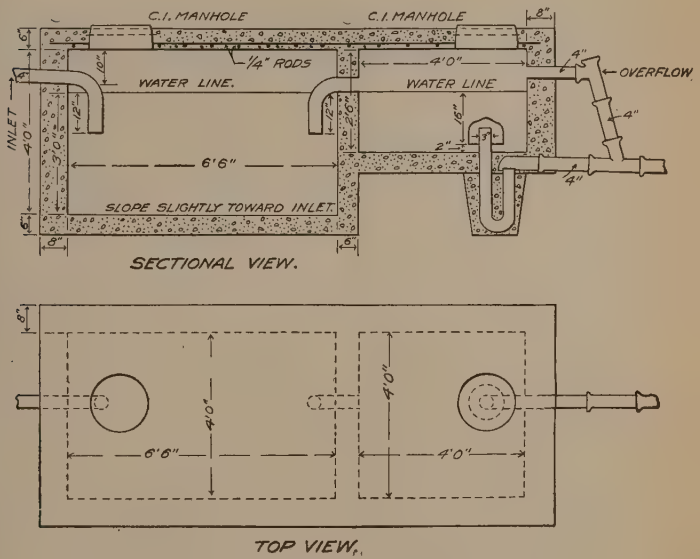


FIG. 129.—Double-chamber septic tank for eight people.[2]

"The plans shown here are for a tank suited to the uses of the ordinary household of from five to ten persons, and, with a fair amount of intelligent attention, it will accomplish its purpose excellently, removing from the rural

[1] See Bulletin, September, 1906, vol. ii, No. 5.

[2] U. S. Department of Agriculture, Bulletin on Water Supply, Plumbing, and Sewage Disposal for Country Homes.

or suburban home a factor which is gradually becoming a distinct menace to the public health."

"This plant consists of two tanks, the first the septic tank proper, the second, a discharging tank. The septic tank is, in construction, practically a cistern 4 feet in diameter and about 3 feet deep. The sewage from the house enters this tank through a lightly trapped pipe, the flow from the ordinary household preventing the back-flow of air. Across the center of the tank is a wall which divides it into two chambers of equal size. The height of this wall is exactly to the point of outflow.

"The sewage from the house enters the first chamber of the septic tank with considerable force, causing some disturbance of the contents. The flow over the dividing wall into the second chamber, however, is even and slow, so that the contents of the second chamber are not disturbed and the flocculent matter settles readily to the bottom.

"The bacterial action on the contents of this tank is often so complete that there is no appreciable residue or sludge, and in this case the tank will rarely, if ever, have to be cleaned out. In some instances, however, the tank will require occasional cleaning. The sludge from a well-constructed tank is not offensive, and may be disposed of without difficulty.

"The sewage is carried into the discharging chamber (which is a cistern 6 feet in diameter and about 4 feet in depth), through a deeply trapped pipe. The second or discharging tank should be of sufficient size to hold the overflow from the septic tank for a period of 12 to 24 hours. At the bottom of the discharging tank is an automatic siphon which is opened automatically when the effluent reaches a certain height in the tank or chamber—a height of about $2\frac{1}{2}$ feet. Through this siphon the contents of the chamber will pass in a very few moments, at which time the siphon will automatically close and the chamber will again refill.

"From the siphon a pipe conducts the effluent, which is

usually entirely without odor and is inoffensive in every way, to the place of discharge, usually on a lawn, provided

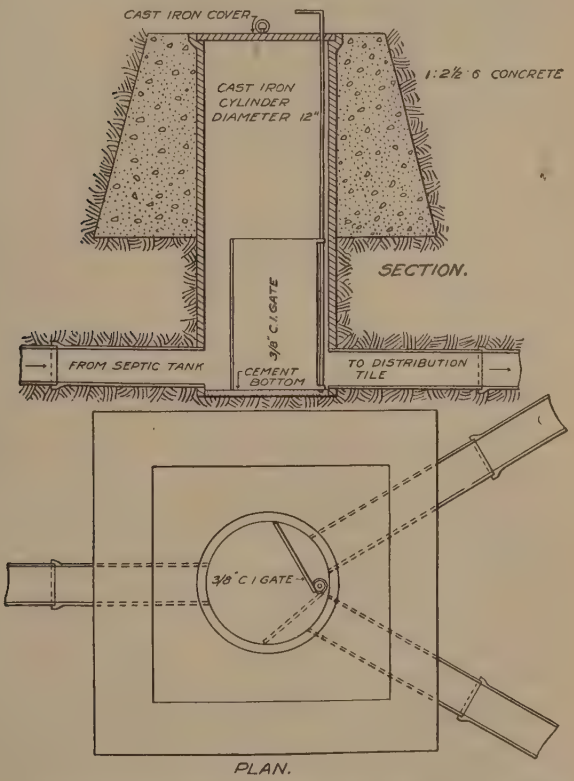


FIG. 130.—Plan and section of sewage-diverting gate. (U. S. Bulletin.)

it is well undertiled and drained, or in a pasture or field."

According to the Bulletin of the U. S. Department of Agriculture on Water Supply, Plumbing and Sewage Disposal for Country Homes, "Single-chamber septic-tank systems may be made to give fair satisfaction if

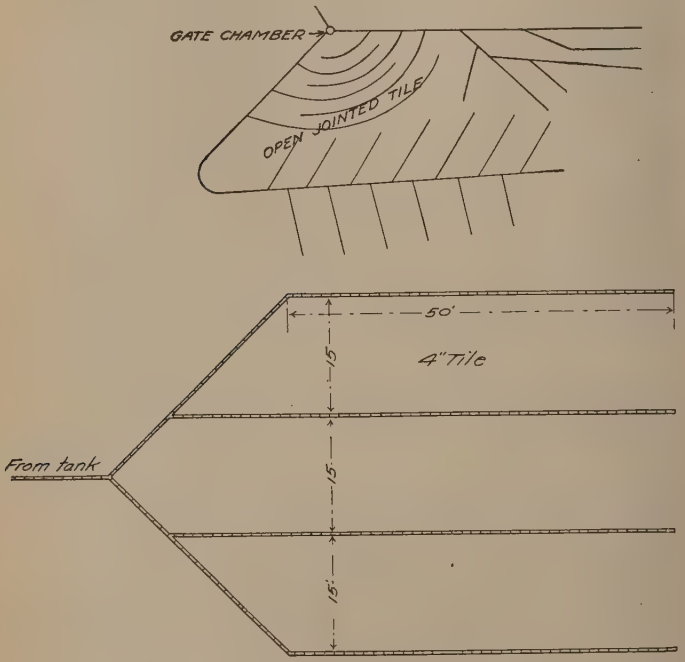


FIG. 131.—Ground plans of tile sewage-disposal systems.

properly designed and operated. On such a system the sewage is received, settled, partially purified, and discharged by one chamber.

"There is necessarily considerable disturbance of the sewage in the tank and, in addition, the discharge is con-

tinuous. This makes necessary two disposal systems, with a diverting gate to allow an occasional breathing spell for each system. If such an arrangement is not used, the disposal system must be of much larger capacity than for the double-chamber tank system in order to prevent the continuous discharge from waterlogging the system.

"If a single chamber tank is used, it should be designed and constructed with elbows at inlet and outlet and with baffle boards before these openings to break up the current."

A somewhat similar provision for the disposal of the sewage of not only single dwellings, but even of large institutions, such as hospitals, schools, country clubs, etc., is the so-called Ashley system. In this the chief features are the "biological tank" and the "nitrification duct or subsoil bacteria bed."

In the former, which is "so constructed as to induce rapid sedimentation of the solids and so gauged as to produce for the bacteria the most favorable conditions for growth possible, without consuming all the oxygen in the sewage before discharging the tank effluent into the nitrification bed," the anaërobic action takes place and about one-fourth to one-third of the purification of the sewage is effected. The latter, which "performs the final and *real* process of purification," by oxidizing and nitrifying the liquefied organic compounds coming from the biological tank, is so built from common building materials as to "cause the liquids to be completely divided and scattered through its interior, and so contrived as to cause air to circulate constantly through the granular materials of which the duct is composed, thereby causing a very decided aërobic bacterial action therein by means of the trickling fluids coming in contact with the aërobic film covering the filtering media." The final product is practically pure water, and is usually taken up by the surrounding soil, making it unnecessary in most cases to discharge it into a neighboring stream or lake.

This system has the advantages that the component parts and the whole are always planned and installed for

ANAEROBIC PROCESS
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the exact work which it has to do, that it is underground and so out of sight and inoffensive in every way, that it is not affected in its biological functions by frost, and that it practically requires no attention after being once properly constructed and installed. A half-hour's time once a year is sufficient to care for an ordinary residential plant.

"The septic tank, although air-tight and supposedly water-tight, should be located as far from the house and the well or spring as convenience and local surroundings will permit, thus reducing the danger of pollution or nuisance in case of leakage or improper operation of the system. The sewer from the house should be of vitrified sewer pipe, usually of 4-inch size, with tightly cemented joints, and should be laid to a grade not less than 9 inches per 100 feet. Where the fall from the house to the tank is excessive, it is a good idea to lay the last 100 feet of tile to the minimum grade to break up entrance velocity."[1]

It should always be remembered that any sewage-disposal plant can only do a certain amount of work, and therefore must be designed to meet the conditions under which it must operate. Regarding these conditions, Frankland says: "The recent experimental work on the bacterial treatment of sewage . . . shows most conclusively that the best results are achieved by separating the phases in which the bacterial purification takes place, allotting distinct places to the anaërobic and the aërobic organisms respectively engaged on the work.

"The anaërobic bacteria are supplied along with the sewage, and practically no difficulty arises in retaining their services on the works beyond that of providing them with space and time in which to carry on their labors. The aërobic bacteria, however, demand air in addition to space and time, and if this air be not provided in sufficient quantities they go on strike, and leave the works, their

[1] United States Department of Agriculture, Bulletin on Water Supply, Plumbing, and Sewage Disposal for Country Houses, p. 38.

place being taken by their less exacting anaërobic brothers, who are, however, unable to finish the work of purification.

"There is, then, the constant tendency for the overflow of the anaërobic bacteria into the aërobic department of the works, if there be any stinting of air in the latter. In order, therefore, to insure the services of the aërobic bacteria being retained on the premises, it is desirable to provide for the aërobic bacteria at least two workshops through which the sewage, on coming from the anaërobic department, is made to pass.

"The first of these aërobic workshops it may be difficult to provide with adequate ventilation, the result being that both anaërobic and aërobic bacteria will here be found competing with each other, and that the aërobic organisms will be unable to complete the work of purification. The sewage, however, on passing into the second and better ventilated workshop will there fall almost exclusively into the hands of aërobic bacteria, which it will, under proper management, leave as an inodorous, almost pellucid liquid incapable of putrefaction."[1]

Another writer summarizes as follows: "As compared with the process of chemical precipitation and sedimentation, the bacterial process presents the following advantages: (*a*) It requires no chemicals. (*b*) It produces no offensive sludge, but only a deposit of sand or vegetable tissue which is free from odor. (*c*) It removes the whole of the suspended matter, instead of only about 80 per cent. thereof. (*d*) It effects the removal of 51.3 per cent. of the dissolved oxidizable and putrescible matter, as compared with the removal of only 17 per cent. effected by the present chemical treatment. (*e*) The resultant liquid is entirely free from objectionable smell, and does not become foul when it is kept; it further maintains the life of fish."[2]

The following table of results is given as an example

[1] See Francis Wood's Practical Sanitary Engineering, p. 216.
[2] American Year-book of Medicine for 1900, p. 549.

of what may be accomplished by a proper combination of the septic tank and aërobic filter-bed, and also serves to show that the reduction in total organic solids, free ammonia, etc., is not entirely completed by the anaërobes in the former, but is continued by the later action of the aërobic organisms when they are given opportunity to work:

TABLE SHOWING CHANGES IN SEWAGE UNDER BIOLOGICAL ACTION.

	Parts per 100,000.				
Sample.	Number of records.	Organic solids in suspension.	Free ammonia.	Albuminoid ammonia.	Oxygen absorbed in 4 hours at 80° F.
Sewage . . .	18	28.50	2.154	0.972	5.019
Septic tank .	16	3.80	1.716	0.340	2.184
Filter, 1 foot .	16	0.16	0.036	0.052	0.328
Filter, 2 feet .	16	0.05	0.020	0.037	0.286
Filter, 3 feet .	16	0.06	0.009	0.031	0.244

Disinfection of crude or effluent sewage may at times be deemed necessary or advisable. For this purpose, various agents have been suggested and sometimes used, but on the basis of availability and expense, especially where considerable quantities of sewage are involved or the treatment is to be more or less continuous, experience has narrowed the selection to chlorine and its compounds and those of copper. Of these, chlorinated lime (often called chloride of lime or bleaching powder) and copper sulphate are the cheapest and most used, the former being more active, requiring less time and being less susceptible to organic matter. As in all other efforts at disinfection, sufficient of the germicidal agent must be used, there must be thorough mixing, and sufficient time for action must be given before the sewage is diluted further or discharged into a stream. The quantity of disinfectant needed per million gallons of sewage will depend upon the state or degree of clarification of the latter, but with a good effluent the cost of disinfection need not be excessive.

Electricity has also been suggested as an agency for the purification of sewage, but in most localities is still too expensive for the purpose. In the Webster process iron electrodes are used, and the favorable results are supposed to be due partly to the hypochlorites which are formed from the chlorides always present in the sewage, and partly to the carbonates and oxides of iron, which not only deodorize but also help to oxidize rapidly the organic matters. By this method about 70 per cent. of the putrescible matters and almost all the bacteria are removed from the sewage, but it is still rather costly on account of the large amount of iron consumed.

The selection of the method of sewage disposal has in the past been made too hastily or without sufficient consideration by some communities, with correspondingly unsatisfactory results. In all cases, careful and scientific tests, covering the several seasons of the year, and taking into consideration local conditions and factors, should be made not only of various methods, but of different combinations of methods, sufficient time being taken to determine the value of each. A decision arrived at in this way will be most likely to prove satisfactory and to be the most economical and salutary to all concerned.

For extended discussion of the problems relating to the removal, treatment and disposal of sewage, the reader is referred to the text-books on Sewerage by Folwell, and on Sewage Disposal by Kinnicut, Winslow and Pratt.

CHAPTER XV.

INDUSTRIAL HYGIENE AND OCCUPATIONAL DISEASES.

The marked increase in recent years of social thought and consideration of all that pertains to human labor have given greater and wider importance to the subject of industrial hygiene than ever before. The question, "Am I my brother's keeper?" has a novel insistence, and the intimate relationship between capital and labor, employer and employed, and the community and the worker are more clearly defined.

Moreover, modern conditions present new problems. Complicated machinery has supplanted hand labor and complicated processes have developed from those that were essentially simple. Busy workshops with enlarged outputs add harmful dusts, vapors, moisture, etc., to the environment of the worker far beyond the safety limit. Specialization and fast speeding keep the nerve strain of the operatives at high tension for long hours. Overcrowding in factories and other places of employment favors insanitary conditions and increased danger from infection and injury. Transportation adds new perils, as electric roads are added to those of steam and as motor carriages, trucks and cycles and self-propelled devices of all kinds multiply beyond number on streets and roadways. Carelessness and ignorance jeopardize the safety of the new laborer or of him who does not continually appreciate his risks, and fatigue is a positive factor for disaster, as is shown by the greater proportion of accidents in the later part of the working day.

That the field of opportunity and service is enormous is patent when we realize that there are approximately

25,000,000 wage-earners in this country of whom more than one-half are engaged in manufactures, trade and transportation, and that, according to the Efficiency Society, "from one-third to one-half of the lives of all wage-earners are spent in their places of occupation, generally within doors, and subject not only to industrial accident but also to lowered vitality, illness, disorders and diseases arising in part, at least, from their conditions of employment." Another authority states that 30,000 wage-earners are killed and 1,500,000 wounded by industrial accidents annually; also that there are 13,000,000 cases of illness each year among industrial workers, all this causing an annual financial loss of nearly $750,000,000. Moreover, at least one-fourth of this great total is probably avoidable and almost one-half of the sickness is preventable.

On the other hand, all the ills and disaster that befall wage-earners must not be attributed to, or blamed upon, their occupations. They are subject to the insanitary conditions of their homes and their communities, many of these under their tolerance and with which their employment or employer has nothing to do. They are liable to the same infections that come to others by way of water or food or through contact. Some are vicious and dissipated and waste their health and lives as well as material substance in riotous living. Others are careless and perhaps ignorant of proper sanitary precautions about the home and concerning the person. All these may have sickness and trouble in full measure, no matter what their occupations.

Even in the factory or place of work, the harmful conditions may not be inherent or essential to the occupation. Only one part or process of an industry may be dangerous, and this risk may possibly be minimized or eliminated by special safeguards and extra care. Perhaps the entire nature of the occupation from the health standpoint may be changed by proper attention to cleanliness, ventilation and proper humidity of the atmosphere. The

removal of dust by readily installed blowers and conduits would remove the harmful feature of many trades. Perhaps the length of working day, time for rest, or the high tension due to speeding, rivalry, or even the temperament of an inconsiderate employer or foreman has more to do with causing poor health, especially among women, than the work itself. Thus due thought should be given before an occupation is classed as necessarily dangerous or unhealthful.

For the same reason, caution must be had regarding the inconsiderate use of what may be termed the vital statistics of occupations. Many statistical tables are fallacious because the influence of important and varying factors affecting their construction has been overlooked. Thus, age, sex, race, heredity, etc., all help to determine the healthfulness and the length of life of an individual perchance even more than does the nature of his vocation. Add to these the effects of personal habits, home surroundings, etc., upon the welfare of the individual, and it will be seen that the outside influences that actually modify the health or the longevity of a large proportion of the workers in a given occupation must be many and positive. That there are dangerous trades, harmful processes and devitalizing pursuits, no one denies. The caution is that we do not seek to find too much in hastily prepared or carelessly considered tables of occupational statistics, and that especial care be had in comparing the life data of various and possibly dissimilar industries.

Rosenau[1] well says that "in order to improve the hygienic conditions under which people work, and in order to prevent the diseases of occupation, five fundamental conditions are essential: (1) investigations; (2) laws; (3) factory inspection; (4) penalties; (5) education. It is self-evident that before anything may be accomplished a careful study must be made of the facts. These investigations must include not only scientific studies,

[1] Preventive Medicine and Hygiene, p. 915.

but economical and sociological factors. Suitable laws are necessary, for it has been found in practice that the conditions cannot be corrected by an appeal to voluntary reform. To be effective the laws must provide ample ways and means for their energetic enforcement. A systematic factory inspection is necessary in order not only to protect work people against preventable diseases of occupation and to correct sanitary defects, but also to enforce the laws concerning hours of occupation, child-labor and related subjects. These laws have little force unless they provide a penalty both against the employer and the employees. Either party to the contract should be held legally responsible in case of violation. Finally, education directed to the employer, the employee, and also to the public at large is necessary to obtain and sustain the laws and maintain the standards."

A matter of much importance is the measure of the day's work. It is not practicable to have a period of fixed duration for all because of the varying conditions and circumstances in different employments and for the same employment in different localities. Necessity often demands long-continued and strenuous effort and this may be the routine from day to day, but wisdom indicates that the customary task should not demand the maximum physical or nervous effort of the worker. There should be a constant store of energy in reserve; in fact, where possible, an increase instead of a depletion of that store.

While heavy physical labor is in itself exhausting and should limit the number of hours of work, even more so is work requiring fixed mental attention and activity or high nervous strain, and if both muscle and brain are heavily taxed, then safety demands short hours with intervening periods of rest sufficient for thorough reparation. On the other hand, where the demands upon the system are variable in their intensity and more or less routine and automatic, calling for no extreme or long-continued strain, the day's work may be long and yet

satisfactory. Nevertheless, there should always be care that each worker should have his full quota of time for healthful sleep, eating and the proper enjoyment of life.

In many trades and occupations the eight-hour day has been adopted or the tendency toward it is strong. This has meant a decided change in many instances from former custom where ten hours or even more represented the usual day's work. But from carefully collected reports it would seem that if due attention be given to details and essential efficiency, the shorter hours may be equally advantageous to both employer and employee, and without financial loss or detriment to either. In fact, in purchasing labor as well as selling it, the question of fatigue should be kept in mind. When the worker tires his work will drag and will not be as efficient as when he is rested. This loss coupled with the cost of power, light and other overhead charges for the extra time may, as has been proved in a number of establishments, more than counter-balance the apparent loss from shorter hours. Reference has already been made to the increase in factory accidents as the work-day lengthens. Workmen's compensation laws which provide for the recompense of injured employees may give an added interest to this and become another argument for shorter hours.

"The enactment of laws limiting actual labor to eight hours a day finds ample support in a study of the relation of fatigue to accident liability and can also be defended upon general health principles. This is especially true of females, who, on account of their imperfectly developed muscular system and more delicate physique, require special protection."[1]

In some occupations where the nervous tension or stress is high it may even be advisable to establish short rest periods of ten minutes or so to the number of two, three or four during the working day, and some experi-

[1] Kober and Hayhurst: Industrial Health, p. 75.

ments along this line in certain industries have apparently demonstrated the advantage of this not only in increasing the output of product but in decreasing the turnover of labor.

Women and Children.—Of paramount importance in all discussions of industrial hygiene are the questions that pertain to the labor of women and children. So much depends upon the proper conservation of all the inherent vigor and vitality of these essential elements of the body politic that any abuse of them is a social crime involving harm not alone to the weaker members of the community mass but to all. The children of today are the adults of the next generation, and the women are the potential mothers of those who are to follow. For our own sakes as well as theirs we cannot afford to permit practices or customs that tend to interfere with the education, stunt the full physical, mental and moral development, or prematurely age and weaken the vitality of the immature members of society. So, with equal wisdom, must provision be made that those who are to bear the children that are still to come shall have every reasonable protection against overtaxation of their energies and whatsoever may tend toward the degeneration or suicide of the race.

According to Rosenau, New York was the first State in this country to pass a factory act regulating child labor. This was in 1886, when thirteen years was fixed as the minimum age at which children might begin to work in factories. Since then many other States have passed similar laws and in almost all of them, as well as now in New York, the minimum age has been placed at fourteen. A number of the States regulate the number of hours per day and per week during which the child may work, and some prohibit work at night, especially by girls, and in certain dangerous trades and in occupations involving exposure to temptation. In Massachusetts in 1910 "the State Board of Health was given power to declare from time to time whether or not any particular trade, process

of manufacture, or operation, or any particular method of carrying on such trade, process of manufacture, or operation is sufficiently injurious to the health of minors under eighteen years of age employed therein to justify their exclusion therefrom."[1] The Board of Health has power of discretion, however, to determine whether such processes may not be carried on with reasonable safety when certain precautions are observed and guaranteed. A recent innovation, as in Pennsylvania in 1915, is the requirement that children at work between the ages of fourteen and sixteen shall attend continuation schools for a specified number of hours per week, the hours of labor being limited accordingly.

"No child should be permitted to work in factories and wage-earning occupations under the age of fourteen, and then only upon presentation of a medical certificate that it is free from physical defects. Such children should not be obliged to work longer than six hours, with two hours interval of rest after the first three hours. Under no circumstances should they be permitted to perform night work. The same may be said of individuals between the ages of sixteen and eighteen years, who, however, may be permitted to work eight hours a day with proper intervals for meals and rest."[2]

That the hours of women who labor at arduous or exacting trades or occupations should be regulated is evident to every student of the question, and also that reasonable allowances should be made for absence or lessened work at certain periods. Full provision for cessation from factory or similar employment with continuing pay both before and after child-birth is also essential. The Swiss law specifies a total of eight weeks for this interim, which is none too short for the mother's future health and safety. Of marked importance is the influence of strenuous labor outside of the home upon both the birth-rate and infant mortality. Statistics

[1] Harrington, Preventive Hygiene, 5th edition, p. 678.
[2] Kober and Hayhurst: Industrial Health, p. 75.

show that it is very much to society's selfish interest to study this question most carefully and to evolve necessary laws and regulations not only for the protection of the individual women who must work for a wage, but even more for the sake of its own ultimate welfare and safety. Even in occupations that are not considered extra hazardous or strenuous and that seem natural or appropriate for women, there is much room for consideration for the workers.

Factory Sanitation.—While certain occupations must necessarily be dangerous, in spite of reasonable precautions, because of poisonous minerals or chemicals or harmful dusts, gases or vapors involved, many trades or pursuits that have hitherto been classed as unhealthful have been so because of the failure to maintain ordinary sanitary precautions and to provide proper apparatus for adequate ventilation, removal of dust, regulation of humidity, etc. A dirty factory or shop in a dusty trade with no sanitary rules or orders against promiscuous expectoration needs only one tuberculous employee to scatter the germs that will start a series of cases that persist and increase in number from year to year until eventually the occupation itself is looked upon as dangerous and all its workers as specially liable to consumption. And so with other infections; whereas a clean shop with abundant sunlight, good ventilation, careful removal of dust, and strict orders as to sanitary personal observances under penalty of loss of employment or heavy fines, would actually minimize the liability to infection for all of its employees. So novel and unusual is the absolutely clean and sanitary factory that even in those trades that have to do with the preparation or conservation of our food, we find that cleanliness is made a matter of advertisement and as worthy of attracting great attention instead of being taken as a matter of course.

So common have been the faults and laxity in this respect in the past and so prone is human nature to sacrifice the welfare of both employees and public to apparent finan-

cial profit, that competent and efficient factory inspection is essential in order that the rights of all may be protected. Such inspection must be conversant with the requirements of the law in all its details as it applies to the occupation and particular place in question, and must deal justly with the employer as well as the employee, and particularly with the community at large, which may have more at stake than either of the two. The inspector must note the provision or absence of all that makes for better work, better health and better living, and for such a sanitary state that, excepting what is unavoidably inherent in the nature of the occupation, disease and impaired health can have no excuse for origin or persistence in that factory or shop. One particular duty of the inspector will be to note the ages and the hours of employment of working children; another, to advise and, where he has the authority, to insist upon such devices as will protect the workers against preventable accidents as well as harmful poisons, dusts and vapors; and still another, to collect and collate facts and data upon which improved legislation may be based and economic and social progress may be advanced.

Harmful and Dangerous Occupations.—The limitations of the present work do not permit an extensive discussion of even the more important occupational diseases, but some suggestions as to their classification may enable the reader to appreciate their extent and their bearing upon public health in general.

"An exact classification of occupational diseases is difficult, as we have as yet no standard nomenclature for this class of diseases, nor do they differ essentially in the majority of instances from the pathology and clinical picture of diseased conditions in general. For the present we may divide them into three general classes, viz.:

(*a*) *Specific occupational diseases*, which include all diseases caused by industrial poisons or specific organisms which enter the system in the course of employment and are traceable to definite materials used; also diseases and

sequelæ caused by exposure to increased and diminished atmospheric pressure.

(*b*) *Systemic occupational diseases*, include all disorders caused by the movements, position of the body, over-exertion, dust and fumes and abnormal working conditions, such as excessive heat, cold, moisture or sudden changes.

(*c*) *Occupational diseases of special senses and organs* include all affections due to exposure to defective or intense light, excessive heat and noises, mental and physical strain, repeated motion, mechanical pressure, toxic and caustic agents, shock, etc.

"But even a classification of causes is not exact, as many of the diseases contracted in industrial pursuits are due to a combination of causes and the so-called predisposing factors play a very important role."[1]

Oliver makes the following general subdivision:[2]

1. Diseases due to gases, vapors and high temperatures.
2. Diseases due to conditions of atmospheric pressure.
3. Diseases due to metallic poisons, dusts and fumes.
4. Diseases due to organic or inorganic dust and heated atmospheres.
5. Diseases due to fatigue.

The above would seem to overlook the infectious diseases, such as anthrax, tetanus, glanders and hookworm disease, one or another of which may have a close relation to an individual's occupation. Moreover, a disease may have such varying factors as to place it in more than one of the above divisions.

Hanson[3] classifies all occupations practically as follows:

"1. Those which are intrinsically dangerous to health by reason of the nature of the materials involved, or by reason of the conditions which arise from the industry or by one or more processes of the industry.

2. Those which are carried on under conditions which

[1] Kober and Hayhurst: Industrial Health, p. 1.
[2] Rosenau, loc. cit., p. 922.
[3] Harrington, loc. cit., p. 655.

are not indispensable to the industry or to any of its processes and which promote susceptibility to disease.

3. Those which involve exposure to mechanical violence and are dangerous to life and limb rather than to health."

The difference between the first and second classes is that in the second the harmful conditions are essentially avoidable, while in the first class some of the factors are unavoidable while others may or may not be so. The third class scarcely comes in the domain of hygiene and need not be discussed further.

"The line of division between these two (first and second) classes is not a sharp one, and some occupations may be said to belong to both classes. For the purpose of considering the specific factors in industries which are inimical to the health of the workers, occupations may be divided into the following groups:

Group I. The occupations or processes which are of particular hygienic interest and give rise to the most clearly defined and wide-reaching occupational diseases or poisonings are those which involve exposure to—

1. Irritating and poisonous dusts.
2. Irritating and poisonous gases and fumes.
3. Infective or parasitical matter in dust.
4. Abnormal atmospheric pressure.

Group II. Of distinct importance, though not always giving rise to definitely proved occupational diseases or poisonings, are occupations or processes which involve—

1. Prolonged use, strain, pressure, fatigue.
2. Excessive heat.
3. Dampness.
4. Offensive gases and vapors.

Some occupations are conducted under such conditions that they may properly be regarded as belonging to a number of subgroups. Mining, for example, may be considered under Group I, 1, 2, and Group II, 1, 2, 3, 4; and cigar-making under Group I, 1, 2, 3, and Group II, 1."[1]

[1] Harrington, loc. cit., p. 656.

From the foregoing it will be noted that dust, whether irritating, poisonous or infective, is an important factor in determining the healthfulness of many occupations, and that if its prevention or prompt removal can be provided for, what has been looked upon as a dangerous trade may become a comparatively innocuous one. And, as such prevention and removal oftentimes depends simply upon the installation of proper hoods and exhaust apparatus, healthfulness may be merely a matter of reasonable expenditure of money and strict enforcement of appropriate legal regulations.

Likewise, a similar enforcement of sanitary provisions may do much to ameliorate the condition of the workers in those pursuits wherein heat, humidity or harmful gases and vapors are the harmful factors, and to develop a sane appreciation of the value of the health of the laborer as contrasted with the comparatively small outlay necessary to bring about and maintain the improved conditions.

Harmful gases may do serious harm and cause even fatal results in various ways: (*a*) Though inert in themselves, by displacing the oxygen of the external atmosphere and thus causing partial or complete asphyxiation. Included in this category are nitrogen, hydrogen, carbon dioxide, etc. Thus nitrogen, which comprises almost 80 per cent. of the normal atmosphere, would quickly smother those who breathed it if increased to 90 per cent. or more. (*b*) By causing internal asphyxiation by inhibiting the oxygen-carrying function of the red blood corpuscles. Carbon monoxide is the chief, if not the sole, offender of this type, but less than 1 per cent. in the air may be sufficient to cause rapidly fatal results. (*c*) By acting as a direct poison to the protoplasm of the body cells. Hydrocyanic acid and arseniureted hydrogen are examples of this type and both act disastrously in low concentrations. (*d*) By irritation of the mucous membrane of the respiratory tract and thus causing serious inflammations of the latter. Among such gases are chlorine,

ammonia, sulphur dioxide and the fumes from sulphuric, hydrochloric and nitric acids.

"Chlorine gas in the air breathed to an extent of only 0.001 per cent. is highly injurious to man, causing cough, dyspnea, bronchial catarrh and, if excessive quantities are breathed, great respiratory distress and rapid death. Hydrochloric acid fumes, on the other hand, are much less irritant. When the proportion reaches 0.005, toleration becomes difficult. Nitrous acid fumes are a grave source of poisoning, if such a term can be correctly applied to a gas setting up, when inhaled in concentrated form, inflammation of the lungs with all its accompanying symptoms of respiratory distress. Onset of the acute symptoms is often delayed for from twelve to twenty-four hours after inhalation of the fumes, the workman meanwhile being able to continue at his work. The explanation of this is that time is needed for the inflammation to bring about the exudation into the smaller bronchial tubes and air vesicles which may eventually completely fill them.

"Hydrofluoric acid causes, even in weak solutions (0.02 per cent.), irritant symptoms of catarrh of the mucous membrane of the respiratory tract, lachrymation, etc. Strong solutions set up obstinate ulcers, difficult to heal, in the mucous membrane and skin."[1]

Reference has been made in another chapter to the fact that dust made up of hard and sharp particles is more irritating and harmful than that in which they are soft and smooth. Thus, it has long been known that workers in metallic dusts had a high incidence of both pneumonia and phthisis, and that, other factors being equalized, the frequency of the latter disease decreased in various occupations accordingly as the dust particles became softer and less angular as well as less in quantity.

To enumerate all occupations or processes in which dust is prevalent and harmful would be difficult. Among

[1] Kober and Hayhurst: Industrial Health, p. 846.

the most important of these, however, may be mentioned steel grinding of all kinds, glass grinding, pearl-button making, stone cutting, work in tobacco factories, cotton or linen mills, and where chemical or poisonous dusts are prevalent.

As may be inferred, the amount of atmospheric dust varies greatly in different occupations. Thus, Miller and Smyth found 218 mg. per 100 cubic feet of air, Winslow, 780 mg. in an abrasive factory, and Winslow, Greenburg and Reeves have reported 5500 mg. per 100 cubic feet of air in the sand-blasting department of an automobile factory. But the latter investigators state:

"The enormous weight of dust present in the air of the sand-blasting cabinet is, however, chiefly due to the large particles of sand present. These large particles are of no particular significance in connection with respiratory disease since, as South African investigators have shown, it is the particles below 10 microns in diameter which actually enter the lungs and produce fibrotic changes. The one-fourth standard unit particles in the air of the sand-blast cabinet (60,880,000 per cubic foot) may be compared with 66,790,000 found by Miller and Smyth in the cement mill and with 31,010,000 and 159,780,000 found by Winslow, Greenburg and Greenberg in two abrasive factories. The actual health hazard involved in sand blasting, with no protection at all, would be about equivalent to that actually existing in the abrasive factories in question. The discomfort due to the larger particles present would, however, prevent any such complete exposure in practice."

It should be kept in mind that not all dusts in the air are harmful. In the Laboratory of Hygiene of the University of Pennsylvania a large number of rabbits were subjected for six hours daily during thirty consecutive days to an atmosphere averaging approximately 1,000,000 particles of calcium hydrate per cubic foot, the average size of over 97 per cent. of the particles being 0.0001 mm., thus being "small enough to gain access to the remotest

air spaces of the lungs." In addition, some of the rabbits were inoculated with a virulent culture of tuberculosis germs, either before or during the dusting experience. Some were killed at the end of the thirty days, and others at the end of each month thereafter for five months, all being carefully examined pathologically and microscopically.

The conclusions of Dr. Iszard, the investigator, were as follows:

"Calcium hydrate dust is not harmful to the lungs of rabbits. It apparently acts as a mild stimulant, causing the migration of macrophages which remove traces of silica present in the calcium dust. The harmlessness of calcium hydrate dust may be attributed both to its physical and its chemical nature. The roundness of its particles prevents them from doing marked injury, and their tendency to coalesce prevents many from gaining access to the finer bronchioles. Moreover, the fact that it is soluble in the body fluids permits of its partial removal by way of the blood stream.

"When inoculation with tubercle bacilli follows a period of lime-dust inhalation there seems to be a very slight retardation in the development of tuberculous lesions, which, nevertheless, are indistinguishable from the customary lesions of this infection in rabbits.

"When the lime-dusting occurs after the inoculation with tubercle bacilli, there is a more distinct retardation of the tuberculous development, explainable possibly on the ground that the lime causes an overproduction of macrophages which render inert the tubercle bacilli. Since the lime is soluble in the body fluids, there is no noticeable accumulation of foreign mineral matter.

"As dissolved calcium is in the blood stream always as bicarbonate and phosphate, the excess, introduced by such experiments as have been detailed, must be deposited in those organs normally characterized by a high calcium content, such as the bones, kidneys and lungs. In a tuberculous condition where we have a calcium demineral-

ization, any increase in calcium whould tend to balance the existing deficiency and permit of an approach to normal."

The poisonous metals most frequently used commercially are probably lead, arsenic, phosphorus, chromium and mercury. Of these the first two may be carried into the system

FIG. 133.—Steel and iron workers at emery wheels. Showing effective front and side guards for their protection against the inhalation of dust particles. (Illustration supplied by Dr. W. C. Hanson for Massachusetts State Board of Health.)

in the form of dust, although they are also ingested in other ways; the other three are usually absorbed through the skin and mucous membrane of the mouth or are taken in as fumes and vapors. Lead is employed in a very large number of trades and processes—probably over 100—so

that cases of lead poisoning are by no means uncommon. Frequently the patient has only his own carelessness

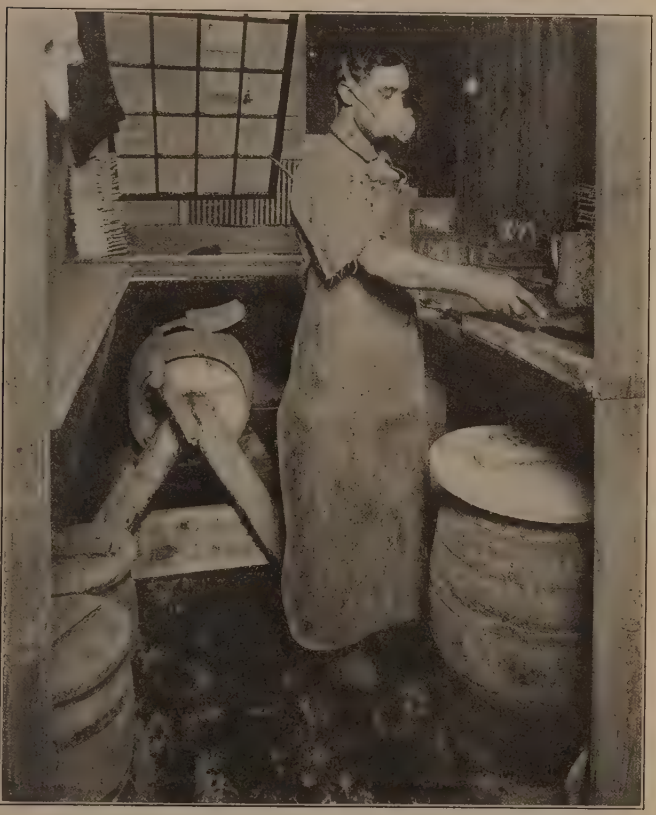

FIG. 134.—Lead working in the manufacture of storage batteries. In mixing peroxide of lead and litharge employees are exposed to lead poisoning. The employee shown was wearing a respirator, but was not willing to wear long gloves. (Illustration supplied by Dr. W. C. Hanson for Massachusetts State Board of Health.)

to blame for his ill-health, but it is also often due to the lack of proper precautions and hygienic control of conditions on the part of the employer. In many cases of lead poisoning, the metal has entered the system in the form of dust or fumes, and seems to be more dangerous in this way, the absorption probably occurring through the lungs as well as stomach. On the other hand, it is frequently ingested by the mouth, being carried thither on soiled hands or fingers; in these cases, attention to ordinary hygienic precautions on the part of the workers should prevent a large proportion of the cases, and the use of proper respirators should be equally efficacious with regard to those of the first class. In all places where the workers handle or come in contact with lead ample provisions, including a supply of hot water and soap, should be made for washing and, in some cases, bathing, and those exposed to the metal should be required to make frequent and regular use of such provisions. Eating places should be entirely apart from the place of work.

The occurrence of phosphorus poisoning has been greatly lessened in recent years by the prohibition in a number of European countries of the use of white phosphorus in the manufacture of matches, and by a heavy tax upon their manufacture in the United States and federal laws forbidding their importation after January 1, 1913 and their exportation after January 1, 1914. So also processes in which mercury poisoning formerly occurred, such as gilding and mirror making, have been so changed that few, if any cases now occur in those trades. There is still some risk in the felting industry in which the fur or hair is sometimes treated with mercuric nitrate, and in occupations in which metallic mercury and amalgam is much handled. Arsenic is used in a large number of trade processes and in those in which much dust is prevalent, there may be considerable risk to the workers.

Chromium is used in the tanning industry and is a cause of local inflammations of the skin and mucous membranes, causing severe and intractable ulcers.

The list of occupations in which the prevalence of irritating or poisonous gases or fumes is a factor in causing ill-health among the workers is a long one. Carbon monoxide, from whatever source, is a very dangerous gas, and so is chlorin, Pettenkofer asserting that 60 parts of the latter gas in 100,000 of air will cause death. Fumes from the strong acids, nitric, sulphuric and hydrochloric, are intensely irritating, as is ammonia, and may cause acute or chronic respiratory trouble. Other substances used commercially and giving off dangerous or harmful gases or vapors are wood alcohol, naphtha, nitrobenzol, aniline and other nitro derivatives, carbon disulphide, etc., and anyone of these may be the cause of most serious or fatal results. The importance of frequent and thorough examinations of all who work in the presence of poisonous metals or vapors should be emphasized and the duty impressed on those who are apt to develop a false sense of security through carelessness, habit and familiarity with the respective dangers.

Tuberculosis can scarcely be considered an occupational disease but it is the chief cause of death in many occupations where dust is excessive and irritating and where rules against expectoration and uncleanliness are not enforced. Maladies more truly related to occupation are anthrax, which may occur among those who handle hides, horse-hair and wool, and glanders and foot-and-mouth disease, to which hostlers and stockmen are exposed. Ankylostomiasis or hook-worm disease, while prevalent in the southern United States and in certain parts of Europe, frequently occurs among tunnel- and mine-workers, and hence is sometimes called miner's anemia. It is evident that the incidence of the foregoing and all other parasitic occupational diseases may be greatly lowered by disinfection and other prophylactic measures.

Dr. H. F. Smyth, of the University of Pennsylvania, has shown that anthrax is more prevalent than commonly supposed, and reported 123 cases with 16 deaths connected with the tanning industry in Pennsylvania from 1910 to

1921, inclusive. For the five-year period for which he could secure accurate statistics, the cases represented a yearly morbidity-rate of almost 2 per cent. He says: "Anthrax continues to be a decided menace to both the cattle and goat-skin tanner and will continue to be so until some method is developed whereby tanneries cease to receive anthrax infested raw stock." Also, "We feel very strongly that all disinfected imported stock should be disinfected at one or more centrally located government disinfecting stations before being shipped to the tanners, as the English government is doing at present with wool and hair."

As for hook-worm disease, "Stiles estimates the number of victims in the United States at 2,000,000 and the economic loss from inability to work at $100,000,000 per annum," while Ashford believes about 90 per cent. of the workers on the coffee and sugar plantations in Porto Rico to be infected with the disease.

It should not be forgotten that septicemia and localized septic infections are common among laborers of all kinds, but especially among those subject to injuries and who handle or are much in contact with unclean things, such as offal, hides, unclean grease, rags, etc. Workers in the soil may develop tetanus after apparently trivial injuries, and those who work with or about horses or cattle may respectively incur glanders or foot-and-mouth disease, especially if either of these maladies are prevalent among the animals of a community. Other sporadic or rare infections may occur at almost any time and should not be disregarded in cases of doubtful diagnosis.

So also the means of prevention, protection or improvement in diseases due to excessive heat or humidity, or to fatigue, strain, posture, etc., are obvious and the long list of such affections need not be detailed here. A peculiar malady is that to which workers in compressed air, as in caissons and under-river tunnels, are subject. It comes on after the worker returns to atmosphere under normal pressure, and is marked by headache and severe

pains in the back, legs and abdomen, rapid pulse, sweating and more or less motor paralysis. Death may occur in a short time in some cases, but most cases recover completely, especially under treatment, which consists mainly in subjecting the patient again to the high pressure and then reducing it very gradually. It has recently been demonstrated that this trouble is due to the absorption of nitrogen gas from the atmosphere under the abnormally high pressure, and that the painful symptoms are probably caused by the sudden and too rapid escape of this gas from the blood.

Regarding prophylaxis in general, the following by Hanson is most appropriate.[1]

"It will be noticed that the disastrous effects attributed to occupations are in very large part due to non-observance of the principles of general hygiene, and chiefly to inattention to that most important sanitary measure, perfect ventilation. It will have been noted that the conditions which bring about impairment of health may be reduced very largely by a constant supply of fresh air. With proper attention to this matter and improvement in the home and home influences, greater attention to the character and preparation of food, and a more general observance of the beneficial influence of active out-door exercise, no very great difference would be noted in the health of the various classes of work people, and the expression, *occupational diseases,* would lose whatever significance it now has."

On the other hand, however, all that pertains to industrial hygiene will be a matter of moment and real importance to all who are interested in the public welfare and the health of the body politic, and whether that interest be chiefly in the line of investigation, legislation, industrial supervision or popular education, much remains to be accomplished before conditions can be satisfactory and sanitary for the worker and conducive to the safety

[1] Harrington, loc. cit., p. 677.

and common health of the general community in which he lives. Proper protection for the adult men as well as for the women and children, proper allotment of time for rest and recreation as well as or work, and proper attention to all details that affect the bodily health of each one who labors at a daily task are essential in order that the public at large may be safe and truly prosperous.

CHAPTER XVI.

TOURIST AND VACATION HYGIENE: CAMP SANITATION.

The country has always attracted multitudes to it for recreation and the enjoyment of their vacation periods, but never in such numbers as in recent years. The growing custom of granting the employees in many lines of business a definite vacation time each year has released many who seek to find the greatest change and enjoyment at least cost, while good roads, the great increase in the ownership of motor vehicles and general prosperity have combined to enable countless thousands to travel far afield or to find and develop camping resorts nearer home. Such opportunities should be of great benefit and doubtless do yield stores of health and happiness to many to strengthen and hearten them for the duties and stress of the rest of the year, but the multiplicity of the participants in this enjoyment of Nature's bounty, coupled with the carelessness and ignorance of many of them, create risks and dangers of serious moment that should not be ignored but which require careful attention and earnest effort for their prevention.

Another feature of modern life is the summer camp for boys or for girls in which the young people may not only secure the benefits of wholesome country living, but may also learn those things, such as swimming, boating, woodcraft, etc., in which every normal youngster rejoices. That such camps are doing an immense amount of good to the youth of both sexes who compose and enjoy them must be evident to anyone who makes a fair study of them and of what most of them are accomplishing.

Likewise the camps for adults which are increasing in number and which offer many a tired business man or woman opportunity for rest and recreation of most helpful and enjoyable character are to be commended and looked upon as an added opportunity for good living. But the very nature of such camps makes the responsibility all the greater that no harm shall come to their patrons, either young or grown-up, during their stay or, because of some camp fault, after they have returned to their homes.

Those who live most of their lives in a modern city are not likely to give much thought to the safeguards to health that are thrown about them by public health officials and municipal ordinances, or to appreciate how dependent their safety is upon these guardians of their welfare. Pure water, safe food, good sewers and protection against infection are all taken as a matter of course and not requiring consideration, as far as foresight is concerned, by the unofficial citizen. Moreover, his daily routine of living and his close associations with others in the crowded city impose restraints upon him, of some of which he may scarcely be conscious while very appreciative of others. Consequently, when he goes on his vacation all restrictions seem irksome to him and he is inclined to cast them aside. He may have some little knowledge of hygiene and be aware of the dangers of a polluted water supply, contaminated food, etc., but is unobservant and heedless or else willing to take chances in the trust that he is too lucky to incur misfortune from them. The number of postvacation cases of typhoid fever in any large city is a sufficient commentary on the fallacy of such a trust. A little information concerning tourist and vacation hygiene or a little attention to camp sanitation may therefore be of great importance both by preventing a disastrous ending to a happy outing and by ensuring a full measure of health and happiness through the coming months of work and duty.

Those who have vacations and spend them away from home, and that includes almost every one nowadays,

may be divided into those who frequent the most fashionable and noted resorts or who travel *de luxe* and patronize the most expensive hotels either here or abroad, or, on the other hand, those of quieter taste or less affluent purse who spend their play-time in touring from place to place with no prolonged stop in any particular locality, or those who find vacation accommodations in country farm houses or small village hotels, or who go camping either by themselves or with numerous others at some more or less

FIG. 135.—A typical summer-camp group. Waiting for the dinner call.

noted but informal resort. To these should be added, of course, those, both young and adult, who attend and comprise the organized camps already mentioned, and the large and constantly increasing class of moderate means who seek both recreation and mental improvement by traveling in congenial tourist groups both in this country or abroad.

There must always be possibilities of danger where many people commingle together with the likelihood of

disease carriers being among them, but the more fashionable and populous hotels and resorts have so much at stake that they are almost certain to conserve their own material interests by taking all reasonable precautions regarding sanitation, prevention of epidemics or infection, purity of water, food, etc., so that a fair degree of safety is assured their patrons. Considering the large numbers that frequent such places, it is but rarely that serious illness originates in them or that matters for fair criticism arise. However, there can be no cessation of vigilance in this respect, and hotel proprietors and local health authorities should be constantly alert to maintain the highest standards of sanitation throughout the resort.

Tourist Camps.—The automobile tourist of today is ubiquitous and his name is legion. He visits every state and every county and village in each state. Good roads give him easy and rapid transit in every direction, and, not content with these he traverses and explores others not so good. He is often reckless of the rights or welfare of others; more often he is careless of his own safety, not only as regards the speed with which he travels or the personal risks he takes on the road, but with respect to what he eats and drinks and the danger of infection or disease that he incurs. As he approaches almost any town or city of fair size he sees notices of tourist accommodations to be had at private homes, and he also finds that many communities have provided special camping places for him or that these are furnished by private enterprise as a means of securing his custom for food or supplies. Whether he stops at one of these camps or at a private dwelling, he is not apt to note the surroundings and even if he does, he is probably scarcely competent to observe whether these indicate sanitary safety or the opposite. He gives no thought to the relation of the toilet accommodations to the water supply nor to the possibility that a typhoid carrier going that way a few days previously may have left some of his infective germs for him. He buys his food at any roadside stand or takes no heed as to its source and preparation and is willing to accept almost anything because he is "rough-

ing it" and so must not be too finicky. If he camps in the open and mosquitoes are about, he does not think to inquire whether malaria is prevalent thereabouts and so to protect himself against them. In this connection it would be well if every prospective tourist and camper would take the precaution of being inoculated against typhoid fever with the "vaccine" that was so effectively used in the army during the World War, and to carry a mosquito net if he has any thought of sleeping out-of-doors, especially if in a malarial district.

The author has no desire to disparage the pleasures or advantages of motoring nor to discourage those who can make use of it either for recreation or business, but he does feel that every intelligent person should have enough interest in his own welfare and safety to inform himself concerning the most fundamental principles of sanitation and to avoid that which is obviously or potentially dangerous. A little care and observation will not lessen the enjoyment of anyone and may prevent lasting regret. Therefore, the motorist should give some thought as to what he drinks, what he eats and where he lodges for the night.

It has long been known that the water from most shallow wells is likely to be contaminated both because of proximity to sources of pollution and because of improper construction, curbing and covering. One only needs a glance or two to determine whether these conditions obtain in any case, and if they do he would better go thirsty a while longer until he can find a safer supply. Moreover, foresight would provide a vacuum bottle of ample size to carry a sufficient supply, this to be replenished when water of undoubted or probable purity is found. In 1925 the State Department of Health of Pennsylvania made a careful examination of samples of water taken from wells and other sources along the principal highways of the state, and where the water was found safe for use an official notice to that effect was posted conspicuously that motorists and other travelers might have the benefit of the information. Where a water was found unsafe or

of doubtful quality the owner of the source was officially notified and given advice as to its improvement that he might as quickly as possible remedy conditions and secure the notice of official approval. It is interesting to note that of the samples taken from 1031 sources tested, mostly shallow wells, a few more than one-half were approved.

In this connection it is well to note that boiling water, as in the preparation of tea or coffee, not only sterilizes it but frees it of other objectionable qualities as well. Also, that a drop of tincture of iodine in a glass of water quickly frees it of all disease germs without imparting a taste to it, and that tablets for the same purpose, containing a small but effective amount of a chlorine compound, are obtainable and furnish the tourist with an additional measure of protection.

That the traveler should consider the character, quality and condition of the food that he purchases and consumes is obvious, but that many do not is evident from the number of eating places along any main highway that serve doubtful or inferior edibles and yet seem to do a thriving business. On account of the readiness with which it may be contaminated, special care should be observed in the purchase of milk, noting whether it is properly cooled, protected from flies and served in a cleanly manner. If delivered to the consumer in closed bottles bearing the name of an established dairy, the chances are that the milk will be of better quality and safer than if dipped from open cans, for in the latter case it may have come from a near-by farm where there is no sanitary supervision and little care as to its collection, cooling or subsequent handling. Any peculiar taste or indication of souring or staleness should contraindicate its use.

Another potential menace to health lurks in some of the beverages offered for sale at the innumerable refreshment stands, the so-called "soft drinks" of many names and, in many cases, of very doubtful purity and quality. Not infrequently they are made with contaminated water and unwholesome flavoring materials, while those that are

clean and good are not as healthful as pure water or natural fruit juices. In addition, the use of some of them tends to habit formation that may eventually prove detrimental and hard to overcome.

Public tourist camps, whether on state reservations or provided by a local community, should be under the constant supervision of a competent official with some knowledge of sanitation and with sufficient authority to compel the campers using them to maintain them in a state of decency and orderliness. Each tourist party should be responsible for the immediate area it occupies, but there should be some one employed by the authorities to police the whole camp frequently and regularly and to see that no scattered remnants of food, empty cans or other refuse remain to attract flies or detract from an orderly appearance at all times. If purveyors of food and other supplies are permitted in or near the camp, they should be required to maintain the same state of cleanliness and order about their respective premises, and some consideration should be given to the quality and condition of the food and drink that they dispense. This is especially essential regarding those conducting restaurants, cafeterias and the like, for carelessness about a place of this kind will do more to foster a fly nuisance than all the rest of the camp combined.

In locating such camps consideration should be given to the elevation, direction of prevailing winds and the drainage. They should not be on marshy ground or what may become so in case of prolonged wet weather. Nor should they be in the neighborhood of noisy or offensive industries, reduction plants, slaughter houses, etc., that may pollute the atmosphere or interfere with the comfort of the campers. It should not be forgotten that such camps can do much to add to or detract from the reputation of the places that maintain them, and have considerable advertising value, either favorable or unfavorable according to how they are situated and conducted. There should, of course, be an ample supply of pure water. If

this is lacking, the camp should be in some other place. If the supply is ample but of doubtful quality and it can be made safe by comparatively simple and easily controlled methods of treatment, these should be provided and established in good working order before the camp is opened to the public. In this connection it is suggested that tourist parties will find it advisable to carry in their outfits the Army Lyster bag or some modification of it, so that they might always be able and certain of having a supply of reasonably safe water if it is not otherwise to be had.

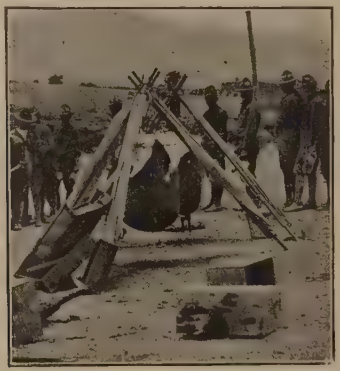

FIG. 136.—Lyster bag supported by stacked litters. (Ford.)

If the water comes from a shallow well the latter should be properly cased, and have a good curb and cover so that surface drainage and splashings may not enter. It would also be better if it were not on the camp ground itself, but that the water should be pumped and piped to the latter. If the water is brought by piping, care must be taken that the areas around the outlets are properly drained and do not become marshy or mud-holes through a wastage of the water. In some tourist camps of the

best class, usually those under private management and where a charge is made for tenancy, both hot and cold water are supplied and various conveniences for dish-washing, laundry work, shower-baths, etc., are provided. This necessarily requires a satisfactory drainage system and methods of sewage disposal.

There is no part of the camp control so important as that which pertains to the disposal of the human wastes, because through these disease may be spread and harm

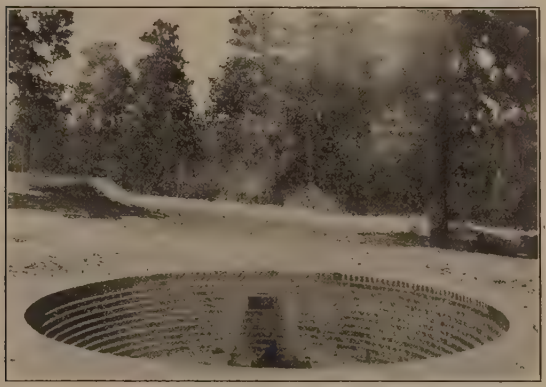

FIG. 137.—Garbage incinerator, with central pyramid to increase draught.

done to many. Neighboring farmers are usually glad to get the garbage and any other waste food to feed to animals, but if this method of disposing of it is adopted, some one in authority must be careful to see that they remove it regularly and completely in covered wagons or receptacles, and that none is left scattered to attract and feed flies and create a constant nuisance. If the applicants for the garbage cannot do this or if the camp is so located that they are not available, some method of cremating the waste must be provided or the more laborious one of

digging trenches and burying it underground each day. The abundance or lack of available fuel and the nature of the ground may help to determine which method is adopted, but it must not be allowed to accumulate, for a good and safe camp must always be a *clean* camp.

Whatever method is adopted for the disposal of the human excreta and whatever conveniences or facilities are provided for this purpose must be under the constant and conscientious supervision of some one with sufficient authority to see that absolute cleanliness and decency is maintained at all times. For it must not be forgotten that the campers will come from many different localities and all classes and stations in life, and that many will be almost absolutely ignorant regarding matters of sanitation and even more grossly careless regarding them. The camp rules must be strict as to the pollution of any part of the camp area or environment and also as to the use and care of the toilet conveniences and buildings. Failure to observe these rules should result in the immediate withdrawal of all camp privileges and orders to depart immediately, no matter who the offender may be. On the other hand, there must be some employee whose chief business it is to see that everything is kept clean and in order, that the excreta is regularly and frequently covered, if the trench method is the one adopted, and proper working conditions are always in force.

Where a sufficient supply of running water can be had, a sewer system should be installed and the excreta, waste water from lavatories, shower-baths, kitchens, etc., disposed of by that means. It will also be advisable to construct some form of "septic" or biologic tank with subsurface drainage or intermittent filters adequate to dispose of the probable discharge, and under no circumstances should the raw sewage be allowed to empty into and pollute a neighboring stream or lake. Special care must be had that it does not affect the water supply of any neighboring community, however small. In case it is not possible to dispose of the excreta, etc., by water

carriage, septic tank, etc., it will probably be best, if possible, to provide deep pits with water-tight concrete walls and bottoms, and to have the added contents covered at least twice each day with a sufficient amount of dry earth to prevent the access of flies or the development of offensive odors. Powdered lime or crude oil may be used in place of the dry earth, but either of these will tend to prevent the biologic action that in due time converts the contents into inoffensive humus. If the walls of the pits and the under-sides of the seats are sprayed with a mixture of oil and lamp-black and the seats provided with a self-closing covers, as they should be in any case, the consequent darkness will help greatly in keeping out flies and other vermin. If for any reason the pits cannot be made water tight, great care should be had to locate them so that there may be no contamination of neighboring wells or water supplies and that even greater precautions are observed in the daily supervision of them. It may even be advisable to burn a small amount of crude oil in them at frequent intervals as a partial disinfectant and to destroy eggs and larvæ of flies, or to see to the daily burning of a layer of dry hay or straw, the resulting ash automatically covering the additions and preventing the access of flies.

If, as in northern localities, the camps are not in use during the late fall and winter months, and if sufficient dry earth has been added daily as indicated, the resulting bacterial action will probably have rendered the contents of the pits so inoffensive by the beginning of the next season that they may be emptied without nuisance and their contents disposed of on the surface of neighboring ground not too close to water courses or wells. Any further steps in the conversion of the waste into plant food will quickly occur, while the probability of any disease germs surviving so long is practically too slight to consider. If during the active season any of the pits should become nearly full, they should be covered with a thick layer of earth and marked by a warning notice,

others being opened in place of them. It is obvious that all out- or "comfort" houses should be located as far from the kitchens and dining halls and tents as reasonably possible, preferably on the leeward side of the camp. But the chief requirement is that they be at all times in a clean, sanitary and inoffensive condition, and a credit rather than a disgrace to the camp.

Some states are already supervising the tourist camps within their respective limits, and it is almost unnecessary to say that this should be done by all states, for there is not one of them to-day into which tourists do not come and in increasing numbers. Moreover, this supervision should be under the respective departments of health even though other state departments or bureaus may claim prior jurisdiction or higher rights of control. This state supervision is especially important and almost imperative on state reservations, not only in order to protect the property of the commonwealth, but especially because visitors, if they find the state lax or negligent in regard to matters of sanitation on its own property, cannot help feeling that it is also careless and inefficient in guarding and promoting the public health elsewhere throughout its territory. In fact, these camps may be one of the best means of advertising the character and efficiency of the care that the particular state gives to the health and welfare of its citizens and visitors. Of course, if the camp is located on a national reservation, the state control and supervision is superseded by that of the federal government.

Vacation Camps.—These may be divided into two classes: The private ones, for the use and pleasure of the single individual, family or limited group of persons; and the public ones for larger groups, either conducted by an individual or company for profit, or by an organization, such as the Boy Scouts, Y. M. C. A. or the like, for the purpose of enabling as many young people as possible to have the benefits and enjoyment of out-door life and of congenial fellowship and associations.

Camps of the first class vary in degree of type and equipment from that of the small boy who, with a companion or two, hikes a few miles from home and pitches his puptent for a night or two in the woods to the most elaborate one that wealth can provide, equipped with all the conveniences of civilization, and that by its very completeness and elaboration robs its occupants of most of the joys of

FIG. 138.—On the way to the swimming hole.

camping and the benefits of getting back to Nature. By far the greater number, however, represent the purpose of and furnish the opportunity to those that establish them of securing the greatest measure of combined enjoyment and benefit attainable during a limited vacation period. Hence the greater reason that ignorance of sanitary precautions and procedures, or carelessness and neglect regarding these shall not prevent these benefits

and even bring disaster and illness in their stead. Better no camp at all than an unhealthful one, and no vacation than one that results in sickness and disaster.

The first requisite of a good camp is a proper and healthful site. While it may be well to have some protection from prevailing winds, especially at high altitudes, there should be no interference with the free circulation of air, and there should also be full exposure to sunlight for a

FIG. 139.—Setting-up exercises, the first part of the daily drill.

portion of the day, although shade may be desirable most of the time. The soil should be dry, porous and readily drained, and the location one that will not become submerged or marshy in case of heavy rains or prolonged wet weather, nor one that can receive the drainage from other camps or from dwellings, stables, etc., on higher ground. Consideration must also be given to the source of the water supply both as regards its convenience and the likelihood of its contamination either previously or during the occupa-

tion of the camp. The place and method of disposing of the camp refuse, especially the human excreta, are vitally related to this and must have serious thought. Thus, if the camp is to be located near a lake or stream from which the water for camp use must be taken, every precaution must be taken that the drainage from the camp wastes either above or under ground does not enter the lake or stream; also, that the drinking water is taken from a place as remote as possible from any other possible pollution, as the boat landing, bathing place, etc.

If the camp is to be a transient or temporary one, it should not be located on ground that has recently been occupied by other campers, and if it is to be of extended duration and tents are used, flooring should be provided for these. Moreover, the flooring should be in sections so that the tents may be readily shifted from one area to another from time to time. Provisions should also be made for ample tentage or cabin space so as to avoid overcrowding except in temporary emergencies. One advantage of a tent is the opportunity it affords for good ventilation, if this be ensured by strict regulations and persistent vigilance. It should not be forgotten that one of the reasons for camping is to secure the benefits of plenty of clean air both day and night. A trench should be dug about each tent to prevent flooding by sudden rains, and at least once each day if the weather permits, tents should be opened as widely as possible, taking advantage of the sunshine as well as the ventilating breezes.

An important detail in the sanitation of a camp and also an evidence of its proper maintenance is the "policing" of it daily or even oftener. The habit of keeping it clean and orderly at all times and of seeing that dirt of all kinds is promptly disposed of is one that should be impressed upon its occupants and that goes far to keep it healthful as well as attractive. Many campers are careless as to the disposal of garbage and of the offal resulting from the cleaning of fish and game. All such wastes should be kept in covered receptacles and disposed of regularly

each day by burning or by burying in the ground to prevent offensive odors and the access of flies. In fact, in a well-conducted camp the common house-fly should be conspicuous by his absence. What has been said regarding the disposal of excreta at tourist camps is applicable here, except that a water-carriage or sewage system will not be practicable for temporary camps or any that are not constructed at considerable expense and that are to be used for more than a single season.

If the camping period is of comparatively short duration and the occupants few in number, perhaps the best method will be to provide a large garbage or refuse can for this purpose and to make it a rule that each deposit in it shall be covered with dry earth, the latter acting as a deodorant as well as preventing access of flies. If the can is large enough it may not need to be emptied until the end of the camping period, but if an earlier disposal is necessary, it can be readily carried to a safe distance from the camp and water supply and the contents buried underground. The contents of such a can should be kept as dry as possible to favor rapid and inoffensive disintegration, and separate receptacles should be provided for the dish water and other liquid wastes of the camp, especially if there be a number of occupants, which should be emptied daily at a place where the contents can quickly soak into the earth but cannot possibly drain into and pollute the water supply. The excreta should never be deposited upon the surface of the ground anywhere in the vicinity of the camp, and if the ordinary pit is used, careful attention must be given to its location and to having the deposits well covered at least twice a day with earth.

Within recent years a large and constantly increasing number of camps have been established in localities comparatively near the large cities or readily accessible by automobile or convenient railroad facilities, and usually contiguous to attractive streams or lakes that afford satisfactory boating, bathing and sometimes fishing. The campers, both young and old, are for the most part

people in moderate circumstances who prefer such a vacation to a sojourn in boarding-houses or hotels and who cannot afford to go farther away, or whose occupation only permit the use and enjoyment of the camp over week-ends and on holidays. The owners of the land find it profitable to rent these camp sites of limited area not only because the income is greater than they would provide otherwise, but also because the campers themselves become near-at-hand customers for garden products and other farm supplies.

Essentially this tendency and desire of so many individuals to get out to the country and to enjoy and gain benefit from life in the open is to be commended as making for public health and happiness, but because of the ignorance of many regarding the most elementary principles of hygiene and sanitation, and also the dangers incident to locating the camps in too close proximity to one another without proper sanitary supervision and safeguards, there are serious risks to health that cannot be ignored. Frequently, if not usually, the local health authorities take no interest in them and give them no attention, partly because of temporary and intermittent nature of their occupation and partly because the campers are not tax-payers and because the owners of the land who find the rentals lucrative and are tax-payers do not wish their tenants annoyed.

In this connection attention may be directed to a somewhat analogous condition that has arisen in the neighborhood of some of the large cities. Improved roads, the general use and ownership of automobiles, high rents and the desire of almost every one to own his home have combined to send thousands beyond the limits of the city in search of a home site. For the fairly well-to-do and those who desire their homes ready-made, the suburbs close at hand, already incorporated as boroughs and with paved streets, water supply, sewers, gas and electricity, leave little to be desired. But further out shrewd real estate dealers, having bought up available farm or other land and dividing this into small lots, sell these, unim-

proved but with vague promises of future development, at low prices to those who plan gradually to build homes for themselves and in the meantime put up a tent or erect a temporary and primitive shack or bungalow for week-end or summer use. The result is that quite a population is thus brought together, but with no common conveniences and no organization for mutual benefit or protection. No matter what he expects in the future, each must provide his own temporary water supply, usually by digging a shallow well, and his own means of disposing of refuse, usually by the primitive and dangerous cesspool, and little or no thought is given to sanitation or to the risks to health that such a procedure entails. Although such incipient communities cannot be termed summer camps, conditions in the two are quite similar and deserve like attention.

Obviously the sanitary supervision and control of all such camps and communities should be primarily under the Department of Public Health of the state in which they are located. for it must be remembered that not only may the individuals comprising them jeopardize their own health, but by polluting streams or other common water supplies or by becoming centers from which infection may be carried back to their homes, may endanger many more than themselves. After inspecting each of them as they develop, eliminating existing sanitary faults, formulating general rules and requirements, and giving necessary advice, the state department can then delegate to the respective county and township officers the duty of regular supervision and control, requiring such reports from time to time as will make it evident that a real protection for all concerned is being maintained.

Regarding other remote and possibly more elaborate private camps, little need be said except that every one using them, and especially the owners, should familiarize themselves as to the fundamental principles of hygiene and sanitation, especially those relating to the care of the person, the contamination and protection of water and food supplies, disposal of wastes, harm from insects

and vermin, particularly mosquitoes, flies and ticks, etc. Often those who have the responsibility of maintaining proper conditions about such a camp are skilled guides whose long experience has taught them the importance of cleanliness, order and decency, but this does not absolve others from reasonable watchfulness and attention to matters that may so readily affect their own welfare.

One precaution that all campers should particularly observe is to be mindful as to the food they eat, both as to quality and character. Away from the routine and restraints of home and usual living, many are inclined to take chances or commit excesses in this respect. While the out-door life and increased exercise will probably enable the camper to digest and dispose of his food better than when at home, on the other hand, unless great care is observed, it is easier for food to spoil or for the camper, unused to matters of cuisine and the selection and preparation of foods, to get and eat that which is unwholesome or dangerous. Keen appetites make reckless eaters and caution is apt to be thrown to the winds. Moreover, stuff of doubtful quality and purity is offered for sale along the highways and is not always what it seems or purports to be, so that the camper or tourist should always buy and partake of it with caution.

Occasionally lumber camps and construction camps have endangered the public health, either by the pollution of streams that were public water supplies or because of infectious diseases, such as smallpox or typhoid fever, developing in them. However, most states in which such camps are likely to be have adopted rules and regulations concerning them and maintain supervision over them, so that the possible harm from them has been largely nullified.

Organized Camps.—A very notable development of recent years is that of the vacation camps for boys and girls conducted by educators or others interested in the welfare of young people. While the first of these for boys dates back to 1881 and that for girls about ten years later, it is only of late that they have become so numerous

that they can be counted by the hundreds and be found in almost all parts of the country, the greater number, however, still being in the New England states. These camps offer to the young people of both sexes great opportunities for recreation and instruction in swimming, boating, wood- and camp-craft, nature study, etc., and have become an essential feature of our social measures for the promotion of health. Like them are the camps under the auspices of the Boy Scouts, Girl Scouts, Y. M. C. A., Y. W. C. A., and many other excellent organizations, both general and local, whose chief aim is to promote the physical and moral welfare of their constituents. And so numerous and general have they become that there is probably no other enterprise or undertaking so productive of good during the vacation months as are these camps, nor that equals what they collectively accomplish.

But just as their potentialities for doing good are abundant, so are the responsibilities of those who conduct them. With the numbers in each camp varying from twenty-five or fifty to a hundred or more, there must be constant supervision and care that no harm come to any one and that there be no condition, if avoidable, present that can be detrimental in any way. This means that matters of hygiene and sanitation must take precedence ahead of every other consideration and that every detail must be arranged and carried out with the chief purpose of conserving and fostering the health of all. In fact, the precaution should go so far as to require evidence that the boy or girl admitted to the camp is free from transmissible disease or infection before leaving home, just as it should be the effort of the camp authorities to return him to his home in better health and condition than when he came.

The selection of the camp site is important. Not only should the place be one of natural beauty and convenient to good and safe boating and bathing facilities, but it should be clean and healthful, with a good water supply good drainage and with a satisfactory and steady supply

of good food readily accessible. It should also be sufficiently distant from anything disturbing or detrimental, either physically or morally, such as noisy factories, railroad centers and shifting stations, public picnic grounds dance halls, road houses, etc. There should, if possible, be sufficient level ground for an athletic field large enough for baseball, basket-ball, volley-ball, tennis, etc., although these need not all be at the same place or on the same

FIG. 140.—A game of volley-ball in camp.

level, and a place for that most important feature of a camp, the camp-fire. This latter should have available space about it sufficient to accommodate the entire personnel of the camp and for plays and other stunts that feature special occasions or add to the general enjoyment at the end of the day.

The sleeping tents or cabins should be on well-drained ground sufficiently shaded, but where the sun may have

access to them for some part of the day when it shines. They should have good floors sufficiently elevated above the ground to allow free ventilation underneath, and if tents are used they should be of the Army-hospital type that will permit the sides being furled at all times except in stormy weather so as to permit ample ventilation. If the camp is permanently established, wooden cabins will probably be more satisfactory in the long run than tents, but whichever are used should only be of a size to accommodate a small group, preferably six or eight and not over ten at the most, including the councillor or advisor

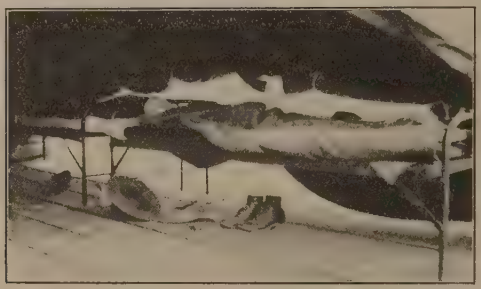

FIG. 141.—Hospital tent, with wall furled for free ventilation.

who should be personally responsible for his particular group and all that pertains to its welfare.

If possible, there should be a recreation hall for use in stormy weather, but this may be a part of the dining hall, or the latter may be used for the recreation hall if large enough. A large stone fireplace adds greatly to the comfort and enjoyment of the recreation hall, which should also contain the camp library, collections of specimens, trophies, etc. The need of this hall in wet weather is manifest and it should be made a part of the camp establishment at the earliest possible moment.

The mess or dining hall should be large enough to

accommodate the whole camp and a reasonable number of visitors, and should be kept scrupulously clean at all times. If walled in and with doors and windows, these should be screened, but the camp should be so conducted as to have few if any flies about it. The kitchen should also be ample in size and well equipped and should have a separate storeroom, so that if ice is not procurable the food supplies may be kept as cool as possible. A "cave" in a hillside or underground serves admirably for this

FIG. 142.—Pyramidal tents: those in the background completely furled to admit sunshine to all parts of the covered area.

purpose, as it did on many an old-time farm. Everything about the kitchen should, of course, be kept clean and free from any possible contamination, and all garbage should be kept in closely covered receptacles until disposed of either to neighboring farmers or by cremation or burial underground. Special provision must be made for the disposal of the dish-water and, because of the quantity of it, this may not be easy. If the ground is well underdrained and there is no danger of polluting the water

supply, a good-sized pit or cesspool may be sufficient and satisfactory; otherwise, it may be necessary to dispose of it by subsurface irrigation or drainage through a considerable length of tiling. The water from the shower-baths may possibly also be disposed of by the same means, this depending on their relative location to the kitchen.

The shower-baths need not be elaborate nor expensive in construction, but should be an essential equipment of every camp of this kind and should be sufficient in number to accommodate all in the camp. If the campers vary much in age, it may be advisable to have two or more sets of showers for groups of different ages. It is the writer's experience that no part of the camp will be more universally used than the showers, both in the mornings after the setting up exercises and at all times during the rest of the day, but especially after games or when the weather is unduly warm.

What has already been said about the disposal of excreta applies here as well. The outhouses should be located as far from the dining hall and kitchen as possible in screened or inconspicuous situations, but not too far from the sleeping tents or cabins as to be inconvenient and to tempt any camper to violate the camp rules regarding ground pollution. The means of disposing of the camp excreta must depend upon circumstances. If there can be an ample supply of water for the purpose, a well-built sewer system may be the most satisfactory and economical in the end, but in many places this will not be possible. If the pit system is used, there must be every precaution against the access by flies or animal vermin, and a reliable individual must be employed whose business will be to see that a covering of earth is applied in each pit at least twice daily. On occasion the use of lime may also be advisable. Some of the modern means of chemical treatment may also be used but in practically every case it will be well for the owners or director of the camp to secure the advice of a sanitary expert regarding this matter and also the water supply. There must be no chance permitted of polluting the latter by the camp wastes

nor any other chance of endangering the health of any of the campers in any way.

As for the water supply, the first requisite is that it should be safe and likewise free from any danger of possible pollution in the future, and next that it should be ample and not likely to fail even in the case of prolonged dry weather. If an ample supply can be found with some slight doubt as to its continuing purity, the advisability of using some reliable means of treatment as an additional safeguard may be considered, but this should only be done after consultation and approval by the state authority or some recognized and reliable expert. This matter of finding a safe and sufficient water supply for any considerable number of persons is by no means an easy one, and the failure to do so should warrant the rejection of what may be otherwise a very desirable camp site. Or again, while the sinking of an artesian well may be a very expensive undertaking, it may be the most satisfactory in the end and help to determine the choice, but before beginning it the advice of the state authorities, including that of the state geologist, should be secured in writing and followed.

The commissary of the camp deserves most careful and continuous attention. It should not be forgotten that boys and girls living out-doors and getting plenty of exercise have enormous appetites and a caloric requirement equalling or even exceeding that of an adult. The food supplied them should be abundant and of the best quality and should be well prepared. Hence the camp cook should be thoroughly competent, clean in methods and healthy; that is, free from any communicable disease. With the appetites that they will be certain to bring to the table, the boys or girls will not desire other than good and plain food, but will want and dispose of plenty of it, especially of good milk, of which there should be an ample supply. There should, of course, be a reasonable variety in the diet, and as the camp will be in the productive season of the year, plenty of fresh vegetables and fruit should be supplied. With these and the milk there will be no question as to a sufficiency of vitamines or of the essential

food principles. Meat need not be supplied oftener than once a day, but like everything else, should be the best procurable. And so with other parts of the dietary. But it should not be overlooked that much of the reputation of the camp will depend upon the character and satisfactoriness of the food served and that many of its other advantages will be rated lower than this one of the table.

The discipline and routine of such a camp should not be too rigid except in regard to certain details. The rule against soil pollution in the camp or its vicinity should be absolute and its violation bring severe reprimand or camp punishment. Setting-up exercises immediately after rising, with a shower-bath following and before breakfast, make a good beginning to the day's routine. There should be some system regarding the disposal of time for the rest of the day, but this should not be too inelastic nor incapable of change on occasion. Close observation of the habits of the boys under his care should be made by each councillor or advisor, especially with regard to what he eats and how much, how he associates and gets along with other boys, and how he sleeps. Any deviation from normal should be promptly reported to the director or head of the camp as well as any complaint as to pain, injury or illness, or any rise in temperature, restlessness, etc.

Each boy or girl should be taught how to swim as soon as possible after arriving at the camp, and how to manage a boat or canoe if safe water makes this possible. Campcraft and woodcraft should be taught as a matter of course, and whatever of nature study can be imparted without taking too much time from other activities. Athletics and sports according to each boy's capacity should also be a part of the daily schedule, or hiking for reasonable distances as an equivalent. No severe exertion or work should be required immediately after meals, and the period between supper and bedtime should largely be one of relaxation and restful enjoyment. Early retiring hours according to the respective ages of the boys or girls, and absolute quiet after the retiring hour for each should be

the rule, so that each one may have his full quota of sleep after a busy day. Camp order and cleanliness should be insisted and made a matter of camp pride. In this as well as in other matters, much may be gained by creating a rivalry between the occupants of the different tents or cabins and awarding camp honors accordingly.

"Parents send their children to camp for several reasons: That they may live out of doors to obtain or maintain strong, vigorous bodies to endure the strain of study incident to the winter months at school; that they may obtain knowledge of woodcraft, athletics, boating, swimming and other things which stimulate bodies and minds.

"When we consider that the boys and girls in our camps are the pride and comfort of their parents and the future parents of other generations, it certainly is no small matter to look after them. Camp owners and directors assume heavy responsibilities when they take charge of these young people to look after their moral, mental, spiritual and physical welfare. The conditions of life are completely changed from their home environment. The important function of summer camps is to return the boys and girls to their homes with improved health, physique and a better mental condition."[1]

Lastly, there are private camps for adults maintained either by organizations to which the camper in some way is attached, or by individuals as a matter of enterprise and business. These are usually well conducted with fair attention given to matters of hygiene or sanitation, or else soon run down and fail for the lack of it. What has already been said applies to this class of camps as well, and the lack of proper precautions and proper sanitary measures and provisions in them is less excusable because the finances for providing them are usually available and because their patrons are more likely to insist upon them. Nevertheless, state supervision and control is just as advisable and sometimes as necessary here as in the case of camps of other types.

[1] C. F. Kendall, Camp Sanitation: American Journal of Public Health, July, 1925.

CHAPTER XVII.

VITAL STATISTICS.

Science is classified knowledge. By arranging known facts and units into groups, and considering them from different points of view, we discover the scope of a particular science, and are also led to the discovery of new facts.

In hygiene it is necessary to have this classification of facts to know what progress we are making, for the true test of any sanitary procedure is its efficacy in preserving health and preventing disease, and we cannot know whether it is efficient or not unless we tabulate and study the results and at the same time eliminate disturbing factors. In this connection it is to be noted that our facts must be accurate and derived from sufficient experience, and that the disturbing factors are especially likely to be numerous.

It is evident that we may study disease by direct observation at the bedside and at the *postmortem* table, or by experiment; and while our knowledge in the past has been gained principally by the former method, we now, since the advent of modern bacteriology and parasitology, may further investigate many diseases by reproducing them in susceptible animals. In this way we soon learn that some diseases are much more preventable than others, and we endeavor to discover the respective causes and predisposing conditions of each that we may the more readily estimate their effects and take measures to restrict and prevent their action.

Our observations may be of two kinds: (1) By noting and comparing individual cases, or by following the track of a particular outbreak or epidemic. (2) By observing

large classes and groups of men, which necessitates a record of births, marriages, diseases, and deaths. The consideration of such records constitutes the study of *vital statistics*, the most important object of which is, as Billings says, "to give warning of the undue increase of disease or death presumed to be due to preventable cause, and also to indicate the localities in which sanitary effort is most desirable and most likely to be of use." The reader will also notice how the study of vital statistics broadens out into the science of demography—the study of the life of peoples and communities.

In fact, demography has been termed "the statistical study of human life," or "the science of human generation, growth, decay and death as studied by statistical methods."[1] But demography comprises much more than the study of registered facts about births, sickness, death, etc., which we call "vital statistics," for it also includes such subjects as genealogy, eugenics, and other studies pertaining to human life in the mass, whether the facts be collected by an official census or from less extensive sources. All these are interesting, but ordinarily they do not have such an intimate relation to hygiene as those comprised in the study and investigations of vital statistics, and must, therefore, have here but a passing reference.

The importance of the science of vital statistics, which has been well termed the "bookkeeping of humanity," is appreciated when we realize that "it points out where and to what extent disease and death are on the increase, and suggests therefore the inauguration of combative sanitary effort, the efficiency of which it enables us to measure. It furnishes the basis for the study of all the various social problems which affect increase and diminution in numbers."[2]

Moreover, vital statistics not only help us to appreciate the value of the human capital of the nation, which far exceeds that of all its more material resources, but also helps in giving information as to the conditions of living

[1] Whipple: Vital Statistics, p. 1.
[2] Harrington and Richardson, Practical Hygiene, p. 879.

and environment of the people, their distribution, growth and progress, and their mutual relations and collective influences upon themselves as individuals. They also aid by giving indications as to the future trend of communities or their future needs, and warrant the provision in advance of ample measures for human comfort, sanitation and health that are certain to be needed by those that come later, but especially do they enable the competent health officer to be warned of the probability of impending epidemics or of the increase of harmful conditions and to take adequate measures against them.

The data which form the basis of any study of vital statistics may be secured from various sources, but are usually derived from the records of the registration bureaus of cities or states, or from those of the governmental census. In former years municipal records were not always reliable and those from some of the states left much to be desired, but at present those from localities within the so-called "registration area" may be taken as fairly accurate and comprehensive.

The national census reports now give statistical returns not only for the wards and other political divisions of some of our large cities, but also for so-called "sanitary districts," in which the population is chiefly made up of those of marked racial or other characteristics that influence the vital problem. The study of such returns supplies much information and the explanation of many otherwise obscure phenomena in the vital statistics of a municipality.

In the study of vital statistics it should always be kept in mind that facts and not merely figures are being dealt with: also that after the collection of the facts there must be a classification and generalization of them before making comparisons or drawing conclusions from them.

At this point it will be well to note certain elementary principles which must be observed in any statistical inquiry, in order that the results of that inquiry may have any value whatever. These are:

1. Our facts, or *numerical units*, must have precise, definite, and constant characteristics. For example, in determining the death-rate or sick-rate from typhoid fever, every case used in the calculation must be accurately diagnosed and must be undoubtedly one of that disease. If there is any doubt as to preciseness, it is necessary to omit that unit.

2. The units are to be arranged into *groups*. These groups must have dividing characteristics so definite that there can be no doubt into which group each unit will come. No unit must be in more than one group at one time. It is difficult to group complex facts so as to analyze them properly and to discover all possible phases.

3. Having decided and arranged the groups, we must have a *constant numerical standard* by which the relation of the various groups to the total units may be expressed. It is generally 100 or some multiple of 100.

4. We must determine the *variation* in the proportion or relation of the component groups to the whole in similar series of cases. While only an approximation to an invariable proportion may be had in any one series, it may be shown mathematically that as the number of units in the series increases there is lessened variation and a greater probability that the proportions will approach uniformity, and that we may calculate the limits of variation by Poisson's formula, as follows: If m be the number of units in one group in the formula $m + n = q$, and n the number in the other, the proportion of m to q will be $\frac{m}{q}$, and of n to q, $\frac{n}{q}$, and these proportions will vary in succeeding series within the limits indicated by $2\sqrt{\frac{2\,m\,n}{q^3}}$. Consequently, the greater the value of q, the less comparatively will be that of $2\sqrt{\frac{2\,m\,n}{q^3}}$, or the limit of variation from $\frac{m}{q}$ and $\frac{n}{q}$.

Example: Suppose that in a series of 1000 cases of diphtheria 700 recover; then, according to the above formula, the limit of possible variation in another series of 1000 similar cases would be 40, and the recoveries would be between 680 and 720; whereas, in a like series of only 100 cases the limit of variation would be 13 and the probable recoveries would vary between 63 and 77.

"Numerical statements of measurements are accurate as they approach the true value of the thing measured, they are precise as they approach the mean of the measurements. Accuracy takes into account unbalanced as well as balanced errors; precision is concerned with balanced errors only. It is possible for results to be precise and yet to be erroneous."[1] Balanced errors are such as, for example, may be due to the personal equations of several observers whereby the faulty tendency of one may be counterbalanced by that of another in the opposite direction; whereas unbalanced errors are such as are all in one direction, as those due to an inaccurate instrument. "Causes of unbalanced errors must be removed, if possible or, if not removed, the results must be corrected for them."

The *arithmetical* mean is usually employed in medical inquiries, though the increase in population is often estimated by geometrical progression. The *probable error* or variation from the arithmetical mean is about two-thirds (0.6745) of the *mean error,* which latter is the *mean of the mean error in excess and the mean error in deficiency.* The mean error in excess is the difference between the mean of the series and the mean of all the units of the series above the mean. The mean error in deficiency is the difference between the mean of the series and the mean of all the units below the mean.

The relative value of two series is as the reciprocals of the squares of their probable errors. Thus if the probable error of series A is 10 per cent. and that of B is 2 per

[1] Whipple: Vital Statistics, p. 26.

cent., the value of A to B will be as $\frac{1}{100}$ to $\frac{1}{4}$, or B will be twenty-five times as valuable as A.

The relative value of two or more series is also as the square roots of the numbers of units in the respective series. From the above it is evident that the results from an average cannot be absolutely applied to any particular case, for there is always the chance of such variation as may be determined by Poisson's formula or by the estimation of the probable error. We apply averages to the aggregates of facts, and they will approach exactitude if they are founded on a sufficient number of facts. We must be careful in estimating the value of means and averages and in giving credit or blame accordingly. Guy says: "Averages are numerical expressions of probabilities; extreme values are expressions of possibilities."

Statistical results are frequently expressed by graphic representations (see Figs. 143 and 144), and these are very valuable, especially for class or visual demonstration.

The numerical units employed in the study and the calculations of vital statistics are persons living and persons dead, and the groups into which these units are classified are characterized by such distinctions as age, sex, race, occupation, locality, etc. The sources from which we derive our information regarding these units are two, viz., the *census* or count, which every civilized country makes periodically, and the returns of births, marriages, deaths, and cases of contagious disease made to local governing sanitary bodies, such as boards of health, etc. These latter returns localize the units and help especially in the classifications in which locality is a factor.

"If it is difficult to secure accurate statistics of population obtained by enumerators hired for the purpose and properly instructed, how much greater the difficulty to obtain complete and accurate statistics by the method of registration when the returns are made by large numbers of physicians, undertakers, clergymen, nurses and laymen not properly instructed, not interested in the proceedings and not always understanding the law, with inadequate

laws, and with governments too easy-going to insist on the enforcement of such laws as exist! And yet most of the vital statistics of the country are collected in this way. Worst of all, the people at large do not appreciate the importance of having the most important events in their lives—birth, marriage and death—made matters of public record. The laws relating to the registration of vital statistics are not the same in all states. In Massachusetts a State Registrar in the office of the Secretary

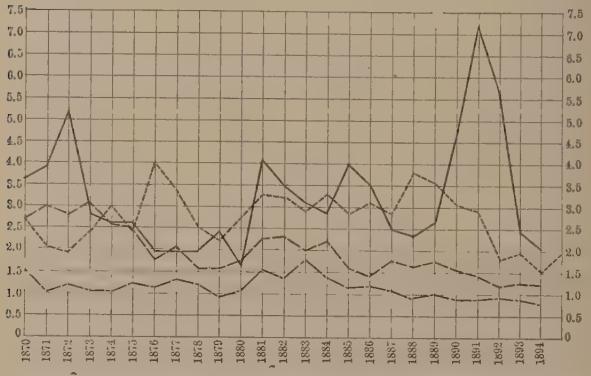

FIG. 143.—Graphic chart, showing percentages of typhoid fever deaths in total mortality in four cities. Unbroken line, Chicago; lower line, New York; short dashes, Philadelphia; long dashes, Boston.

of the Commonwealth has charge of the matter, but in many states the State Board (or Department) of Health has charge. In order to bring about uniformity a model law was drafted and endorsed by a number of national organizations, and this has been adopted by a number of states. Some of the older states, however, still maintain their old arrangement."[1]

[1] Whipple: Vital Statistics, pp. 107–108.

The census returns give not only the population, but also particulars as to sex, age, race, occupation, etc. Of these the age-record is most important, as the death-rate varies most according to age.

The *natural increment* of a population is the excess of births over deaths, but the *actual increment* differs from this, however, according to the difference between emigra-

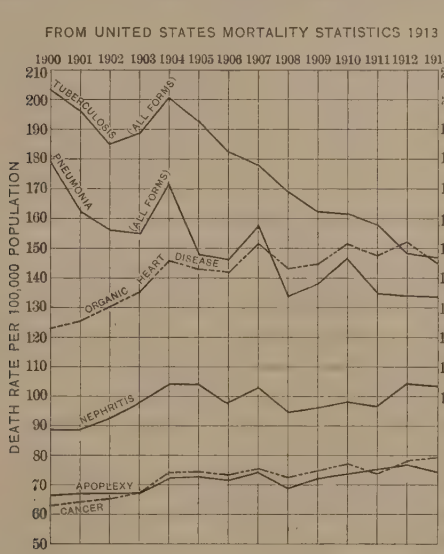

FIG. 144.—Chart from U. S. Mortality Statistics, 1913.

tion and immigration. And as the rate of increase does not always remain the same, estimates of population at times other than of the census cannot be exactly accurate. Thus, we may have a lowered death-rate and yet a decrease in both the natural and actual increment, owing to a greatly lowered birth-rate and to increased emigration, both of which may be primarily due to a long period

of oppression or financial distress. However, to estimate the population for times other than the census year, we assume that the rate of increase, whether positive or negative, that prevailed between the last two census enumerations will continue until the next is taken.

Now, as populations increase in regular geometrical progression when the rate of increase is constant, which we assume, the growth is after the manner of compound interest. Thus, if a population of 10,000 increases by 2 per cent. annually, at the end of the first year it will number 10,200, at the end of the second year 10,404, etc. Hence, it can readily be shown that

$$\text{logarithm } R = \frac{1}{10}(\text{log. } P' - \text{log. } P),$$

where R is the annual ratio of increase, P the population of the census before the last, and P′ the population of the last census. If we now multiply the logarithm of R, the annual ratio of increase, by the number of years since the last census, and add to it the logarithm of the last census (log. P′) we will have the logarithm of the population at the census date of the given year—*e. g.*,

$$8\,\frac{(\text{log. of the pop. } 1890 - \text{log. pop. } 1880)}{10} + \text{log. pop. } 1890 =$$

logarithm of the population on June 30, 1898.

For the reasons already given, such an estimate will not be absolutely accurate, and it would, consequently, be well to have a census taken every five years for certain data. The more accurate the estimate for any year happens to be, the more reliable will be the statistical results. It is also to be noted that in this country the census was formerly taken at the middle of the year, but because this is not the best time of the year to make the enumeration on account of the likelihood of so many people being away from home on vacation, April 15, was taken for the date of the census of 1910, and death-rates, etc., are based on the population estimated, as above, for that date.

Another method of approximately estimating the population is to assume the growth to be by arithmetical progression, and, therefore, to add to the population of the last census one-tenth of the difference between it and the population of the preceding census for every year since the last census. "The arguments in favor of this method of estimating population are that it is simple and easily understood; that in view of the various disturbing factors due to migration and other causes it gives results practically as near the truth as those obtained by geometrical progression; that the estimates for the whole area of a given district will be equal to the sum of the estimates for all parts of the district, which would not be the case with the geometrical method. The U. S. Bureau of the Census has adopted this method and in the interest of uniformity all cities and states should do the same."[1]

We may also estimate the population from the number of houses and use this as a check on either of the above estimates. The number of persons living in each house averages about the same for each city, but differs for different cities. So also the ratio of the school registration to the total population, which is apt to remain relatively constant for any stable community, may be used to determine the population for a given year. Local authorities always tend to overestimate the population, and a police census is invariably too high.

"A knowledge of the number of persons in a dwelling or family is of sociological interest, and it may be of practical use in estimating the population of an area the boundaries of which are not coincident with any civil division."

As has been stated, we get the number of births, marriages, deaths, etc., from the registration records, the proper data being furnished to the registration bureau by duly authorized persons. For instance, the law should require a burial permit for each death in order to identify

[1] Whipple: Vital Statistics, p. 130.

the person and to guard against criminal acts or neglect, and the death certificate on which the burial permit is issued should give the name, sex, color, age, occupation, and especially the cause of death of the deceased. The diagnosis concerning this last item should be as correct as possible, and the primary as well as the secondary cause of death should be given. And while it is difficult to determine the actual cause of death in many cases without, and sometimes even by a *postmortem* examination, there is fortunately not much uncertainty usually in diagnosing the diseases of which we most want statistical information, especially the so-called preventable or infectious diseases.

As a consequence of the above, the certificate as to the cause of death will need to be signed by some one competent to determine that cause, viz., by an educated physician; and it is therefore necessary that the state should define who is and who is not an "educated physician." And as this information and the other required returns which the physician makes, as well as his professional services in general, are for the sake and benefit of the citizens of the state, it is evidently to the state's interest that it be very careful and explicit as to the qualifications of the physicians whom it allows to practise within its borders.

Another reason for the enforced return of a certificate and the issuance of a burial permit for every death is that this is about the only way in which it is possible to secure a record of all the deaths. Any system for collating the list of deaths only at the end of the year will fail to record from 25 to 40 per cent. of the number.

The statements made in the introductory chapter and elsewhere show the importance of vital statistics in determining the sanitary conditions and improvement of communities. In order that comparisons and correct judgments may be readily made, it is evident that all classifications, returns, and registrations should be on a basis or system as uniform as possible, but almost the

opposite has obtained, since almost every state, city, or local authority has used its own system and without any concert of action until comparatively recently. Accordingly, in order to amend this and to secure not only uniform, but also correct and thorough returns from the whole country, the Division of Vital Statistics of the U. S. Census Office is making extraordinary efforts to bring about uniform legislative requirements in the various states and to secure the adoption of the International Classification of Causes of Death, which is intended "to harmonize the features of the most generally used systems in order to afford a common basis of union," and which has been adopted by the U. S. Census Office for the compilation of mortality statistics. To this end a circular has been sent to the physicians of the country "describing the details required by the Standard Certificate of Death (see next page), and giving the titles of the International Classification of Causes of Death, with explanatory notes showing the significance of various terms to the titles under which they are compiled, and a list of indefinite and unsatisfactory terms very frequently used in reporting deaths, with a statement of why such statements are unsatisfactory." This circular is very instructive, and its recommendations should henceforth be observed by all physicians in making death returns.[1]

"More and more it becomes obvious that there is a need of a national system of keeping records of vital statistics, with uniform state laws, and with proper provision for the local use of the data registered. The excellent work done by the Bureau of the Census has done much to emphasize this need. Likewise interstate barriers must be broken down in the interest of suppressing diseases dangerous to the public health. The U. S. Public Health

[1] This circular can doubtless be had on application to the Division of Vital Statistics of the Census Office at Washington, together with a circular on Medical Education in Vital Statistics, relating to the instruction of medical students in registration methods, uses of registration data, and the duties and obligations of physicians; and one on Practical Registration Methods, for the information of local registrars.

8—209. **MARGIN RESERVED FOR BINDING.**

V. S. No. 98. **Write Plainly, with Unfading Ink—this is a Permanent Record.**

N. B.—Every item of information should be carefully supplied. **AGE** should be stated **EXACTLY. PHYSICIANS** should state **CAUSE OF DEATH** in plain terms, that it may be properly classified. The "Special Information" for persons dying away from home should be given in every instance.

PLACE OF DEATH.

County of .....

*City of .....

CENSUS OFFICE.
STANDARD CERTIFICATE OF DEATH.

.....

Registered No. .....

(No. .....

St. ; .....Ward.)†

FULL NAME .....

PERSONAL AND STATISTICAL PARTICULARS.

SEX | **COLOR**

DATE OF BIRTH .....

(Month) (Day) (Year)

AGE ..... *years*, ... *months*, ... *days*

SINGLE, MARRIED, WIDOWED, OR DIVORCED

BIRTHPLACE (State or country)

NAME OF FATHER

BIRTHPLACE OF FATHER (State or country)

MAIDEN NAME OF MOTHER

BIRTHPLACE OF MOTHER (State or country)

OCCUPATION

THE ABOVE STATED PERSONAL PARTICULARS ARE TRUE TO THE BEST OF MY KNOWLEDGE AND BELIEF

(Informant) .....

(Address) .....

Filed .....

..... 190 .....

Registrar

MEDICAL CERTIFICATE OF DEATH.

DATE OF DEATH .....

(Month) (Day) (Year)

I HEREBY CERTIFY, That I attended deceased from .....190 ..... to .....190.....

that I last saw h..... alive on .....190.....;

and that death occurred, on the date stated above, at .....

M. The **CAUSE OF DEATH** was as follows:

.....

.....

Contributory ..... (DURATION) ..... DAYS

.....

(Signed) ..... (DURATION) ..... M. D.

.....190 ..... Address .....

SPECIAL INFORMATION, only for Hospitals, Institutions, Transients, or Recent Residents.

Former or How long at
Usual Residence ..... Place of Death ..... Days

Where was disease contracted,
if not at place of death? .....

PLACE OF BURIAL OR REMOVAL | **DATE OF BURIAL**

....190.....

UNDERTAKER | **ADDRESS**

* If death occurs away from USUAL RESIDENCE, give facts called for under "Special Information."

† If death occurred in a Hospital or Institution, give its NAME instead of street and number.

C—277

Reduced copy of Standard Certificate of Death recommended by the United States Census Office.

Service keeps a record of cases of disease from data furnished by the states and publishes the same in its weekly Public Health Reports. This is only a part of what is needed. If the time ever comes when the United States establishes a real National Health Department, the maintenance of an adequate system of vital records will be one of supreme importance."[1]

The gross death-rate varies with the size of the community. Newly settled communities have a lower death-rate than older ones, because the proportion of adults is larger and of children smaller in the former. With large communities and short periods the probabilities of error are very great, and the longer the period the less likelihood of error. Birth-rates, marriage-rates, and death-rates are usually calculated as rates per thousand of the population living at the middle of the given year, and are determined by multiplying the number of births, marriages, or deaths by 1000, and dividing the product by the population.

What were looked upon as fair maximum death-rates a decade or more ago are now considered to be too high, and the average rate of the present closely approximates the minimum of the comparatively recent past. However, if the death-rates of any community are continuously reported as much below the average for similar populations, the chances are that the population has been overestimated or that all deaths have not been recorded. If higher than this average, there is probably some special cause for the high mortality.

In statistical computations we must exclude the populations and deaths in hospitals, prisons, etc., except for such of the inmates as belong to the district in which such institution is located.

To find the weekly or daily death-rate, the number of deaths for the week or day must be multiplied by 1000 and divided by the so-called weekly or daily population: the weekly population $= \frac{\text{total population}}{52.17747}$; the daily popu-

[1] Whipple: Vital Statistics, p. 127.

lation $= \frac{\text{total population}}{365.24226}$. The monthly population equals the daily population multiplied by the number of days in the particular month.

"The zymotic death-rate is the rate from the seven principal zymotic or infectious diseases, viz., smallpox, measles, scarlatina, diphtheria, whooping-cough, fever (typhoid, typhus, or other continued fever), and diarrhea."[1] It is given per 1000 of population, and in the same way we can give the special rate for any particular disease, but this is now usually stated as the rate per 100,000 of population. For example, the average annual zymotic death-rate for England and Wales for the decade from 1861 to 1870 was 4.11, for 1871–80 it was 3.36, and for 1881–90, 2.35—a striking proof of the decided benefits following proper attention to hygiene and sanitation.

The mortality from certain diseases is affected by age, sex, race, occupation, density of population, seasons, cyclical changes, etc. "In connection with a study of death-rates and causes of death a knowledge of age distribution is fundamental. As a factor in vital statistics it is more important than sex or nationality or parentage or occupation or any other particular characteristic." This is because the mortality-rate is very high in the first year of life, higher in infancy than in childhood, and relatively and progressively higher from year to year in old age.

Contrary to the general rule, the *rate of infant mortality* is not expressed per thousand of population, but measured by the proportion of deaths of infants under one year to the births registered in that year, and is determined by multiplying the number of deaths by 1000 and dividing the product by the number of births.

The infant mortality-rate is always high, owing to various causes, viz., early marriages and weakly parents, hereditary tendencies or diatheses, insanitary surround-

[1] Wilson, Hand-book of Hygiene, 8th ed., p. 570.

ings and unfavorable social conditions, improper feeding, insufficient clothing, infant life insurance, etc.

Death-rates vary greatly for the different ages, being much higher for the first five years of life. For this reason it is well to express the death-rate of children under five as the rate per thousand of children under that age, rather than as a proportion of the total number of deaths. Otherwise, a town with a large number of children might apparently have an abnormally high death-rate. There might also be a difference in the death-rates of two localities due to sex-distribution, for the sexes differ in their susceptibility and resistance to the various diseases. More boys are born everywhere than girls, but more males die than females, so that the tendency is to a preponderance of the latter, except in newly settled countries or localities. Age-distribution and sex-distribution favor a low mortality in rapidly increasing towns, new localities, and manufacturing districts; in rural districts they tend to increase the death-rate.

Consequently, when the death-rates of two or more towns or localities are to be compared, there must be corrections for age-distribution and sex-distribution. The mean annual death-rate of the country for each age and sex for the decade preceding the last census is applied to the town or district, with age-distribution and sex-distribution according to the last census. The total number of deaths thus calculated, multiplied by 1000, and divided by the population of the last census, gives the *standard death-rate* of that town. The mean annual death-rate of the country divided by the standard death-rate gives the *factor for correction*, which being multiplied by the recorded death-rate of any year gives the *corrected* death-rate. The *comparative mortality figure* is determined by multiplying the corrected local death-rate by 1000 and dividing by the death-rate for the whole country, and only indicates that the same population which gave 1000 deaths in the whole country gave or would have given so many deaths in the town or district in question.

"What shall be taken as the number of deaths in a community? Shall non-residents who die within the geographical limits be included? Shall residents who die away from home be referred back to the place where they live? In other words, shall the place for which the death-rate is computed be considered as a geographical area or as a community of persons? The answer must depend upon the use which is to be made of the facts.

"The Bureau of the Census, looking at the matter in a broad way, takes the geographical point of view. It can hardly do otherwise. By recording deaths in the place where the deaths actually occur there is far less danger that all deaths will not be recorded and that no death will be counted twice than if a process of distribution by actual residence were attempted. It may be laid down as a general rule that in computing gross death-rates all deaths within the defined area shall be included and no others; that is, gross death-rates shall have a geographical basis.

"This does not prevent the making of corrections to allow for local conditions. Often such corrections are desirable. If a hospital is located in a suburban town near a large city the deaths in that hospital should be included in the general death-rate of the town; but this figure could not be taken as an index of the hygienic or sanitary condition of the town. For such a purpose another rate—a corrected rate—should be computed, leaving out the hospital deaths. This might be called the *local death-rate*. This rate should not be used in place of the gross death-rate, but in addition to it.

"If besides the omission of non-resident deaths in institutions, the attempt is made to find and include the deaths of residents who have died away from home, we might call the result the *resident death-rate*.

"The gross death-rate, or general rate, is best for purposes of national or state record. The local rate is best for environmental studies. The resident rate is useful for social and political studies."[1]

[1] Whipple: Vital Statistics, p. 189.

The morbidity-rate or sick-rate of a community is difficult to estimate, since there is usually no complete record and registration of cases of disease. Where returns are required to be made of the infectious diseases, the morbidity due to them may be determined in the same way as the mortality for the locality. It is estimated that there is a total of about two years' sickness in a community for every death, and members of beneficial societies are said to average about one and one-half weeks' sickness annually. "Applying this estimate to the United States, in which about 1,500,000 persons die per annum, there are probably at all times about 3,000,000 persons seriously ill. This means an average of thirteen days for each inhabitant."[1]

Like death-rates, birth-rates are usually computed as the number per thousand of population, but should include only living births. However, in some of the earlier registrations still-births; that is, children born dead, were included with the living births, and this should be kept in mind when old records are studied or compared with recent ones. It should also be remembered that in many communities it is only comparatively recently that accurate records of births have been made, and that earlier ones are by no means reliable or suitable for statistical study.

The practical study of the means of preventing the infectious and epidemic diseases would be impossible today without the aid of vital statistics, and we are learning that by the same means much may be learned concerning some of the non-infectious ones. Thus statistical methods are being employed most extensively to discover both the degree and cause of the increasing prevalence of cancer which is still considered a non-transmissible malady by most authorities, and others, such as diabetes and organic heart disease, are being investigated by epidemiological methods.

In studying transmissible diseases in particular, we

[1] Report on National Vitality, Fisher, p. 34.

find that we need to know both the number of cases and the number of deaths due to each; that is, the morbidity- and the mortality-rates, and also the proportion to or percentage of the latter in relation to not only the former but to the total or general death-rate of the population concerned. Thus, "the fatality of a disease is the ratio between the number of deaths and the number of cases, and is best expressed as a percentage," and "the proportionate mortality of a particular disease is the per cent. which the number of deaths from that disease is of the total number of deaths from all causes. The interval of time is usually taken as one year, but shorter periods may be used."[1]

It is by collecting, recording and studying the data upon which these four ratios are based that past achievements in the conquest of such maladies have been demonstrated and new campaigns against them are planned. Therefore, the importance of accuracy and completeness in the collection or reporting of such data and in the registration of them is beyond question, and every one concerned, whether the physician in charge of a case, the health officer to whom it is reported or the registrar that makes record of it, should feel a special obligation to make such data reliable and permanent.

From what has already been said it must be apparent that accurate vital statistics are essential to the welfare of a community as well as to the country at large not only as a means of permanently recording the totality of births, deaths, etc., but also and more especially as they constantly supply information as to the prevalence of infectious disease or give warning of impending epidemics and, in general, serve as an index of the state of public health both locally and for the whole country. Without them the public health official would have much greater difficulty in protecting the people under his care against infection or in maintaining their collective health at its best, while

[1] Whipple: Vital Statistics, pp. 308, 309.

with them he is able to measure the progress he makes and the victories he achieves against the common enemy.

In this connection, the following definitions are given of terms that are employed in discussions of vital statistics, especially in relation to longevity:

The *mean age at death* of a population is the average age at which death occurs in that population, and is indicated by the total of the ages at death divided by the number of deaths. Inasmuch as it depends largely on the age-distribution of the population, it is neither a good test of longevity nor of sanitary conditions, except when it is calculated or taken from life-tables for an entire generation.

The *probable duration of life* is the age at which any number of children born will be reduced one-half, the chances thus being even that each will survive to that age. For a million children the probable duration of life is now probably considerably over fifty years and somewhat more for females than males.

The *mean duration of life* is the same as the mean age at death when the population is stationary as to age-distribution and sex-distribution. Otherwise, it is indicated by the mean after-lifetime.

The *expectation of life* is the *mean after-lifetime* of a person at any age, as indicated by a life-table; or, in other words, it is the average number of years which persons of that age continue to live. At birth it is identical with the mean duration of life, and "as applied to communities, it is the mean lifetime of a generation of persons traced by the life-table method from birth to death, and is the only true test of the health of populations." According to Farr, "a life-table is a barometer which indicates the exact measure of the duration of life under given circumstances, and is indispensable in gauging the influence of sanitary or insanitary conditions."

The essential factors of a life-table are the number and ages of the living and the number and ages of those that die, and these factors are obtained from the mean population

for each age and sex and from the total death-returns between two censuses.

"Contrary to common impression, there is no iron law of mortality. Recent statistics for India show that the average duration of life there is less than twenty-five years. In Sweden it is over fifty years; in Massachusetts, forty-five years. The length of life is increasing wherever sanitary science and preventive medicine are applied. In India it is stationary. In Europe it has doubled in three and a half centuries. The rate of increase during the seventeenth and eighteenth centuries was about four years per century; during the first half of the nineteenth century, about nine years per century; during the latter half of the nineteenth century, about seventeen years per century. And in Germany, where medical and sanitary science has reached the highest development, about twenty-seven years per century. The only comparative statistics available in this country are for Massachusetts, where life is lengthening at the rate of about fourteen years per century, or half the rate in Germany."[1]

The foregoing was written in 1913, but it is now authoritatively stated that the present average length of life in the United States is fifty-five or fifty-six years and that approximately fifteen years have been added to the span of human life in this country since 1870. In fact, the assertion was recently made that there has been an increase of five years since 1910. Not all of this gain, of course is due to the various measures of prevention now invoked against disease and still less to the assistance lent them by vital statistics, but the latter has had its part not only by marking progress but also by showing the ways by which it could best be made. There can be no better source of encouragement to those who are carrying on the work for the betterment of public health and the extension of human life than the statistical records of the last quarter century. They in their reality exceed the hopes and dreams of the most optimistic worker of the preceding generation.

[1] Abstract of Report on National Vitality, Fisher

CHAPTER XVIII.

THE EXAMINATION OF AIR, WATER, AND FOOD.

In this final chapter the author has endeavored to arrange a series of methods for the examination or analysis of the subjects respectively considered in such a manner that anyone who has had a little laboratory experience may be enabled to determine their hygienic conditions, sanitary influence or degree of purity, and this at the cost of a minimum of time and expense.

The methods outlined have been selected from a variety of sources, and some have been especially modified for the purpose; so that while it is not claimed that they will give the absolutely accurate results desired by the professional bacteriologist or chemist, nor that they will suffice as a basis for expert testimony in court or to establish legal rights, it is believed that, if carefully carried out, they will not fail to yield the information sought for, viz., whether the sample of air, water, or food examined is sanitarily pure or safe for use within the accepted limits.

Only such apparatus is to be used as can be readily obtained or improvised without much expense, and every effort has been made to render everything clear to the student and reader, so that he may not hesitate to undertake the necessary investigation whenever occasion requires or an opportunity offers.

For further details regarding any of the methods, should these be found necessary, reference may be made to the text-books indicated, as they will render clear any points that may here seem uncertain or abstruse.

AIR.

The solid impurities in the atmosphere may be collected for microscopic examination as follows: Tightly cork a large glass funnel and fill it with cracked ice. As the aqueous vapor of the air condenses on the exterior,

the dust particles adhere to the moistened glass, and are carried down by the condensed water into a vessel placed below, in which they are allowed to settle. From this they are transferred by means of a pipette to clean slides and examined under the microscope. Other methods that may be used to collect the dust are oiled plates; paper, cloth or cotton wool filters; wash bottles, etc.

To make a qualitative bacteriological examination the air may also be drawn through sterilized glass tubes coated interiorly with gelatin. Bacteria and their spores, moulds, etc., adhere to this coating, and from each individual or group of individuals colonies develop, from which pure cultures and subsequent bacteriological experiments may be made; or the sterilized gelatin may be exposed in flat (Petri) dishes to the air for a short time to allow the bacteria, etc., to fall on the surface. The tubes or dishes are then covered and set aside to allow the colonies to develop.

To make a quantitative bacteriological examination a known quantity of air may be drawn through a small tube filled with sterilized pulverized sugar. The sugar is then transferred to tubes or flasks of melted and sterilized gelatin, and dissolving leaves the bacteria, etc., free to develop in the gelatin, which may be poured upon sterilized Petri dishes before cooling. A temperature just sufficient to melt the gelatin will not be too warm to harm the bacteria. The number of colonies that develop may be assumed to represent the number of living microörganisms in the volume of air drawn through the tube.

The relative humidity or percentage of moisture in the air is determined by some form of *hygrometer*, of which one of the most convenient is the psychrometer, which is simply a combination of a dry- and a wet-bulb thermometer. The latter has its bulb enclosed in a jacket of absorbent wicking, muslin, or silk, which dips into a small reservoir of clean, soft water. The thermometer bulb is thus kept wet by capillary attraction, and, unless the air be "saturated" with aqueous vapor, evaporation

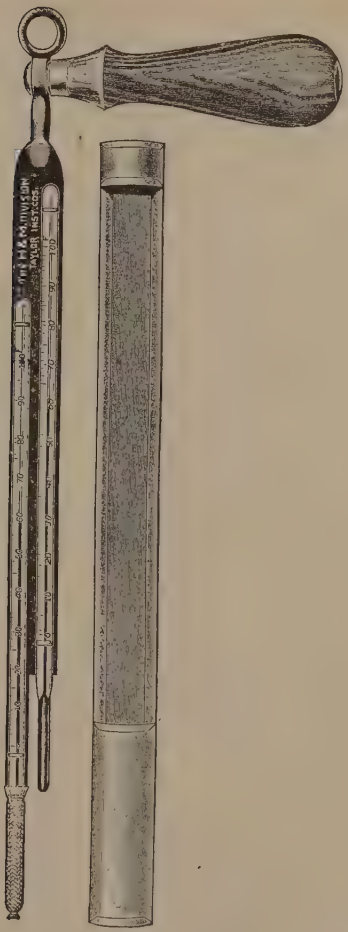

Fig. 145.—Sling psychrometer.

takes place more or less rapidly, heat is abstracted or made "latent," and the temperature, as indicated by this thermometer, is lowered. Hence, by the difference in reading of the two thermometers we may determine not only the relative humidity of the atmosphere, but also the "dew point," weight of vapor per cubic foot of

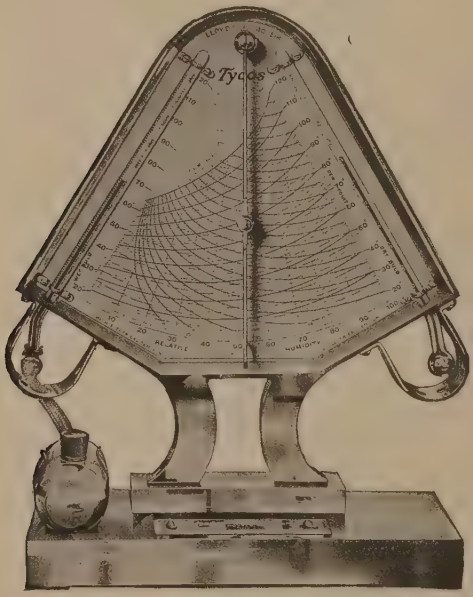

Fig. 146.—The Tycos hygrodeik.

air, and even the "tension" or influence upon barometric pressure due to the presence of this vapor. These results are usually and most conveniently determined by using tables that have been prepared for all variations of temperature and humidity within practical limits, and which are supplied with the instruments. The "*hygrodeik*,"

however, has a chart fixed between the two thermometers which shows graphically by a series of curved lines and a movable indicator all the facts that would be derived by using the official tables. A sling psychrometer is one devised so that it may be whirled rapidly in the air, thus facilitating evaporation from the wet-bulb and lowering to a constant temperature.

Test for Carbon Dioxide, CO_2.—*A Modification of Angus Smith's Method.*—To a moderately large, wide-mouth bottle (one-quart) fit a perforated rubber stopper, the perforation being just large enough to admit the tip of a 1 c.c. pipette; first fill the bottle with the air of the room by filling it with water and then emptying it in the room, taking care that the entering air does not bubble through the out-going water. A better way is to siphon most of the water from the bottle, and then to empty the remainder, thus avoiding absorption of any of the gas by the water.

Fit in the stopper and introduce 1 c.c. at a time of a standardized alkaline solution, slightly colored with a few drops of a neutral alcoholic solution of phenolphthalein; close the perforation with a piece of glass rod and shake the bottle well after each addition of the alkali, continuing until the color ceases to be discharged by the carbonic acid of the contained air. Then, since the quantity used of the alkali solution indicates a certain definite amount of carbon dioxide.

The number of c.c. of solution used multiplied by the amount of CO_2 each c.c. represents, multiplied by 100, *and divided by the capacity of the bottle in c.c. less the number of c.c. of solution used* $= x =$ the percentage of CO_2 in the air examined.

A suitable alkaline solution may be prepared as follows: Dissolve exactly 2.409 grammes of pure sodium carbonate (free from the water of crystallization) in 1 liter of distilled water. Only a fraction, say one-fourth or one-tenth, of this quantity need be made up at a time. Each c.c. of this solution will neutralize 1 c.c. of CO_2.

For use: To 10 c.c. of this solution add a few drops of neutral alcoholic solution of phenolphthalein and dilute to 100 c.c. Each c.c. of this dilute solution is then equivalent to 0.1 c.c. of CO_2, and used as above will give close results. The phenolphthalein is used as an indicator, as the pink or rose color due to it disappears when sufficient carbon dioxide is absorbed to exactly neutralize the alkalinity of the soda solution. The stock solution should be kept in well-filled, tightly stoppered bottles.

Example: If 9 c.c. of the above dilute solution be used, and the capacity of the bottle is 1200 c.c., then

$$\frac{9 \times 0.1 \times 100}{1200 - 9} = \frac{90}{1191} = x = 0.0755,$$

the percentage of CO_2 in the air of the room.

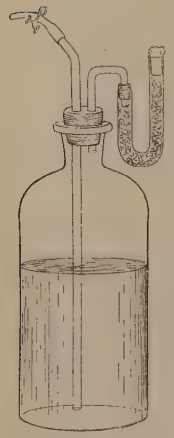

FIG. 147.—Bottle for barium hydrate. (Harrington.)

Pettenkofer's Method.—This test, like the preceding one, depends upon the fact that the acid carbon dioxide in a measured sample of air tends to neutralize the alkalinity of a stock solution of calcium or barium hydrate when the latter is agitated with the given volume of air, and that the amount of carbon dioxide can thus be measured by the loss of alkalinity in the solution. The absorption of the carbon dioxide is more rapid if a solution of barium hydrate instead of lime-water (calcium hydrate) is used, the former taking up the gas within an hour or so, whereas eight or ten hours are needed for its complete absorption by the lime-water. However, the latter, which is a well-known solution of the official pharmacopœia, is more readily obtained and gives equally good results, if proper time be given to the test. The barium hydrate solution is made by dissolving about 4.5 grammes

of barium hydrate and 0.5 gramme of barium chloride in a liter of distilled water, which has been previously boiled to drive off any contained carbon dioxide. The solution, if made up in considerable quantity for repeated tests, is best kept in a bottle with a stopper having a U-tube for an inlet, as in Fig. 147. This U-tube contains small pieces of pumice soaked while hot in strong caustic potash solution, and prevents the ingress of CO_2 from the air when the liquid is drawn from the bottle. In the description of the test the term lime-water will be used to indicate the alkaline solution, although it be prepared with either base.

The Test.—The air to be tested is collected in one or more large, clean bottles, the exact capacity of each having previously been ascertained and noted. The bottles may be filled by pumping in the air with a bellows or by first filling with water and then removing the latter by siphoning or by carefully decanting it, care being taken that the air does not bubble through the water which readily absorbs carbon dioxide.

Into each bottle containing an air sample an exact quantity of the lime-water, say 50 c.c., is introduced, the bottle quickly stoppered, and then well shaken, so that the air may be thoroughly washed with the solution. The shaking is to be repeated at intervals until the necessary time for complete absorption of the gas has elapsed. If the lime-water is measured into the bottles by means of a pipette, care must be had that the delivery is not hastened by blowing through the pipette, since the carbon dioxide of the expired air would thus vitiate the test. The strength of the lime-water, being as yet unknown, is now determined by means of a solution of oxalic acid of such a strength that 1 c.c. corresponds in alkalinity to 0.5 c.c. of CO_2. (Such a solution is made by dissolving exactly 2.808 grammes of pure crystallized oxalic acid in 1 litre of distilled water.)

Supposing that 50 c.c. of lime-water was introduced into each bottle containing air to be tested, exactly 25 c.c.

of the stock lime-water is measured into a clean beaker, into which the oxalic acid solution is run from a graduated burette until the alkalinity of the lime-water is just destroyed, the neutral point being indicated by means of a phenolphthalein solution, which may have been previously added to the stock solution, or a few drops may be placed with it in the beaker. The phenolphthalein retains its color as long as the solution is alkaline, but loses it the moment the neutral point is reached. When the lime-water is exactly neutralized, the exact amount of the acid solution used is noted. Then, after the time necessary to allow the complete absorption of the carbon dioxide in each testing bottle by the lime-water therein, 25 c.c. of that lime-water is measured into a beaker, and the alkalinity exactly determined by means of the oxalic acid solution in the same manner as was done with the stock solution.

Now, inasmuch as part of the alkalinity of the lime-water which was in the bottle has already been neutralized by the carbon dioxide in the air of the bottle, it will require less of the acid solution to neutralize the lime-water from the bottle than was required for the same quantity of stock lime-water, and as 1 c.c. of the acid solution corresponds to 0.5 c.c. of carbon dioxide, the difference in the amounts of acid solution used expressed in c.c. will express the number of c.c. of carbon dioxide in the volume of air in the bottle. For, though each c.c. of acid solution is equivalent to only 0.5 c.c. of carbon dioxide, the loss of alkalinity of only one-half the lime-water primarily introduced into the bottle has been determined, and the total loss of alkalinity would have to be expressed by multiplying 0.5 c.c. CO_2 by *twice* the difference in c.c. between the amount of acid used in testing 25 c.c. of the stock lime-water and that used in testing the 25 c.c. (one-half) of the lime-water from the bottle. But twice $0.5=1$. Therefore the difference between the readings in the two tests gives the amount of carbon dioxide in the air in the bottle. The quantity

of carbon dioxide in the bottle having been thus determined and the quantity of air tested being known by deducting the amount of stock lime-water introduced into the bottle from its total capacity, which has been already found by measuring the quantity of water it will hold, the percentage of carbon dioxide in the air examined is readily determined.

Example: Suppose that 25 c.c. of stock lime-water requires 30 c.c. acid solution and 25 c.c. of lime-water from the bottle requires 27 c.c. of acid solution.

Therefore 30 c.c.$-$27 c.c.$=$ 3 c.c.$=$ amount of carbon dioxide that was in the air in the bottle, which latter contains (for example, say) 2550 c.c. when exactly filled.

Then $\frac{3 \times 100}{2550 - 50} = \frac{300}{2500} = 0.12$ per cent. carbon dioxide in the tested air at current temperature and pressure. To be absolutely exact in the result, correction must be made by bringing the air volume to the standard temperature (0° C.) and barometric pressure (760 mm.), but this is unnecessary in most cases.

The phenolphthalein "indicator" is made by dissolving 0.5 gramme of phenolphthalein in 100 c.c. of alcohol.

Test for Carbon Monoxide.—Ordinarily a canary bird will collapse in an atmosphere containing carbon monoxide in which human beings will feel no distress symptoms, but this test is not always reliable as the bird may survive when dangerous proportions of the gas are present.

During the World War members of the Chemical Warfare Service perfected a detector for carbon monoxide which is simple in operation and gives fairly accurate information as to the presence and amount of the gas, since it readily indicates it in tobacco smoke. "The detector comprises a small metal barrel with a rubber bulb on one end and a means for quickly inserting a glass tube filled with a special chemical in a space on top of the barrel. The detector substance 'hoolamite' contains fuming sulphuric acid, iodine pentoxide and powdered

pumice sealed in a glass tube. The chemical used changes color from a light gray to a green when air contaminated by CO is forced through the tube by the rubber bulb after breaking off the tips of the tube, the amount of color changes depending on the percentage of CO in the air, so that an accompanying calibrated color scale enables one to estimate in a few seconds amounts varying from 0.05 to 1.0 per cent. CO. The instrument is entirely mechanical and any one can operate it. It is far more sensitive than a canary bird and can be carried through gaseous zones. It has been tried out around blast furnaces, steel mills and coal mines with most satisfactory results."[1]

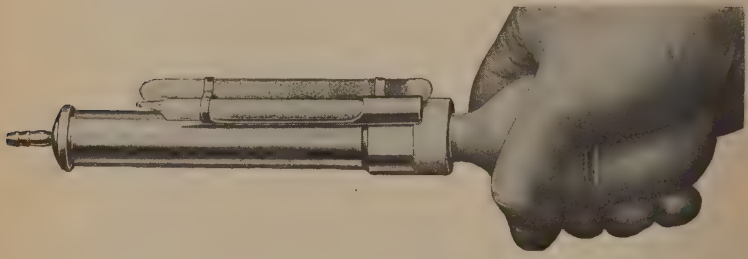

FIG. 148.—Carbon monoxide detector.

For a more accurate testing for carbon monoxide in the air and also for it in the blood, the reader is referred to Vol. 37 or Reprint No. 872 of the U. S. Public Health Reports in which Sayers, Yant and Jones describe quite fully the pyro-tannic method, which they consider the best for all around purposes as it is very delicate and especially valuable for quantitative estimations.

The Katathermometer.—The cooling power, or, in a very warm atmosphere, the warming power, of the atmos-

[1] Kober and Hayhurst, Industrial Health, p. 373.

phere exerted on a surface at body temperature may be determined by the katathermometer and the degree of ventilation existent or needful for any room or other place thus ascertained. This instrument, invented by Prof. Leonard Hill of England, is a thermometer graduated for 95° and 100° F. only. The method of use is to immerse the lower or main bulb in warm water until the contained fluid rises into the small top bulb and the column is free of bubbles. The main bulb is then quickly dried and the instrument is then suspended or held by the stem well away from the body and the time in seconds noted that it takes the meniscus of the fluid to fall from the 100° mark to 95°.

From three to five readings should be taken and the average of these determined. The factor of the instrument, which is inscribed on the stem, is then divided by the average time of cooling in seconds, the result giving the cooling power in millicalories per square centimeter per second. This for the dry bulb, which gives the cooling power by radiation and convection.

For the wet bulb determination, which gives the cooling power by radiation, convection and evaporation, the muslin jacket is slipped over the main bulb and the thermometer warmed and suspended as before, care being had to remove any excess of water from the bottom of the muslin cover each time and several readings being made to get a fair average by which the factor is divided as before. The difference of results from the dry and wet bulbs gives the cooling power by evaporation alone.

In rooms for sedentary workers the dry cooling power should not be below 6 and the wet cooling power not below 11. For places where physical work is done the cooling powers should be greater. If the atmospheric temperature is above 90°, the kata cooling rate is too slow to record; if it is well above 100°, the warming rate may be determined by cooling the thermometer to below 95° and taking the rate of warming from that point to 100°.

WATER.

To test for color, turbidity, etc., compare with distilled water, using tall glass jars and looking down through equal depths upon a white surface. The smell of a water may be detected by heating it to about 140° F. for a few minutes in a glass-stoppered bottle. This test may or may not indicate fecal contamination. Few polluting impurities, when only in moderate quantities, give any taste to water, and a dangerously polluted water may have a good taste. Iron in small quantities, one-fourth of a grain to a gallon, will give a taste to the water.

Use caution in tasting suspicious waters. Aëration is indicated by the lustre of the water and by the presence of air-bubbles on the sides and bottom of the vessel.[1]

Test for Chlorine.—*Solutions required:* (1) Standard nitrate of silver solution: to 1 liter of pure distilled water add 4.788 grammes of pure silver nitrate; 1 c.c. of this solution is equivalent to 1 mg. of chlorine. (2) Potassium chromate solution—a 5 or 10 per cent. solution of potassium chromate made up in distilled water free from chlorine.

Process.—To 100 c.c. of the water add from 0.5 to 1 c.c. of potassium chromate solution, and then run in from a burette or graduated pipette the standard silver solution, adding it drop by drop, and stirring the water with a glass rod. Continue until a faint but permanent orange-red tint has been produced, showing that all the chlorine has combined with the silver, the persistent reddish color being due to silver chromate. The number of c.c. of silver solution used indicates the number of milligrammes of chlorine in 100 c.c., or parts per 100,000; this multiplied by 10 gives the number of milligrammes in 1 liter, or parts per 1,000,000. If the water contains but little chlorine, accuracy will be furthered by evapo-

[1] See also pages 222 to 228.

rating 250 c.c. of the water to 50 c.c. over a water-bath, and proceeding as above; the result multiplied by 4 will give the amount of chlorine in 1 liter. On the other hand, if the water contains much chlorine, the test will be facilitated by using 50 c.c. or even 25 c.c. of the sample, adding a correspondingly smaller quantity of the potassium chromate indicator.

Water containing much organic coloring matter or iron should be decolorized before making the above test by adding from 3 to 5 c.c. of milk of alumina, free from chlorides, to about half a liter of the water, heating to boiling and filtering.

Test for Nitrates.—*Solutions required:* (1) Phenolsulphonic acid: 6 grammes of pure carbolic acid; 37 c.c. of strong sulphuric acid, and 3 c.c. of distilled water. (2) Standard potassium nitrate solution: add 0.722 gramme of fused potassium nitrate to 1 liter of distilled water. Each c.c. of this solution contains 0.1 mg. of nitrogen as nitrates. The water used in making the solution must be free from nitrates.

Process.—Evaporate 10 c.c. of the water to be examined (or 25 c.c. if it is presumably low in nitrates) just to dryness in a small and clean porcelain dish. Add 1 c.c. of phenolsulphonic acid, stir with a glass rod, and add 1 c.c. of distilled water and 3 drops of strong sulphuric acid; warm, and dilute well with distilled water; then add ammonia until the fluid is strongly alkaline, and dilute with water to 50 c.c.

FIG. 149.—Bottle for collecting samples of water at different levels.

Be careful throughout the test, but especially when evaporating, not to dissociate and drive off any of the nitrates by too prolonged or intense heating.

Treat 1 c.c. of the standard solution in an exactly similar manner and compare the tints produced, placing the resulting solutions in two Nessler or other tubes of equal caliber, and diluting the more intense until the tints match exactly; then calculate the amount of nitrogen present by the amount of dilution necessary—*e. g.*, suppose that in testing a certain sample, the tint from 1 c.c. of standard potassium nitrate solution is darker and requires the addition of 50 c.c. more water—*i. e.*, up to 100 c.c. to match the tint of the tested sample. Therefore 100 c.c. : 50 c.c. : : 0.1 mg. N : x = 0.05 mg., the amount of nitrogen as nitrates in the 10 c.c. of water examined. The proportion would be reversed, of course, if the water tested had the stronger tint. The test is based on the facts that some of the phenolsulphonic acid is converted by the nitrates into picric acid, which forms ammonium picrate upon addition of the ammonia and gives a yellow tint to the water, and that the amount of picric acid and picrate formed and the consequent depth of color depend on the amount of nitrates present in the water.

"The accuracy of this test is diminished by the presence of chlorides in notable amounts, say more than 2 parts in 100,000, but not by nitrites. On this account, Mason recommends the addition of corresponding amounts of sodium chloride in the preparation of the color scale."[1]

Test for Nitrites.—*Solutions required:* (1) Sulphanilic acid: dissolve 0.5 gramme of sulphanilic acid in 150 c.c. of dilute acetic acid, sp. gr. 104. (2) Naphthylamine acetate: boil 0.1 gramme of solid naphthylamine in 20 c.c. of distilled water, filter through a plug of washed absorbent cotton, and mix the filtrate with 180 c.c. of dilute acetic acid. (3) Standard sodium nitrite solution: dissolve 0.275 gramme of pure silver nitrite in pure water

[1] Harrington, Practical Hygiene, 5th ed., p. 463.

and add a dilute solution of pure sodium chloride until a precipitate ceases to form, and dilute to 250 c.c. with pure water. For use, dilute 10 c.c. of this stock solution to 100 c.c. Each c.c. of the dilute solution contains 0.01 mg. of nitrogen as sodium nitrite. Keep both solutions in the dark when not in use, preferably in amber bottles. All water in these solutions must be free from nitrites; likewise all water used in the tests, except the sample under examination.

Process.—Place 25 c.c. of the water to be examined in a cylindrical vessel, and in a similar vessel of the same caliber dilute 1 c.c. of the (diluted) standard sodium nitrite solution to 25 c.c. with nitrogen-free distilled water; add to each vessel 2 c.c. of first one and then the other reagent, using a separate pipette for each. "If nitrites are present (in the water tested) a pink to a garnet color is developed within half an hour, the intensity of color depending upon the amount of nitrite present. Since the air of laboratories in which gas is burning is very likely to contain traces of nitrites, which are absorbed readily by water, it is well to keep the tubes corked or otherwise protected."[1] Compare the colors at the end of half an hour, or sooner if the tints seem permanent, and estimate the amount of nitrites by diluting the darker tint until it matches the lighter, and comparing the respective volumes, as in the test for nitrates; the result will give the quantity of nitrogen as nitrites in the water, and should not be more than a trace. The above test is a very delicate one.

Schuyten's Method.[2]—"When 5 c.c. of a 1 per cent. solution of antipyrin in acetic acid (1 to 10) is added to a solution containing nitrites, a green color is produced." Measure 45 c.c. of the water to be examined into a Nessler tube, and in another of equal caliber mix 1 c.c. of the standard sodium nitrite solution (dilute) with 44 c.c. of distilled and nitrite-free water. To each tube

[1] Harrington, Practical Hygiene, 5th ed., p. 463.
[2] Bergey's Hand-book of Practical Hygiene, p. 95.

add 5 c.c. of the antipyrin solution. Allow to stand for one-half hour and compare as above.

"This method will show the presence of 1 part of nitrogen as nitrous oxide in 20,000 parts, and while not so delicate as the other method, is not hindered by the presence of any of the ordinary contaminations in water."[1]

Test for Free and Albuminoid Ammonia.—*Wanklyn's Method.—Solutions required:* (1) Standard ammonium chloride solution: dissolve 0.382 gramme of pure dry ammonium chloride in 100 c.c. of ammonia-free water. For immediate use dilute 10 c.c. of this standard stock solution up to 100 c.c. with ammonia-free water; each c.c. of the dilute solution contains 0.01 mg. of nitrogen as ammonia. (2) Alkaline potassium permanganate solution: dissolve 200 grammes of potassium hydrate (in sticks) and 8 grammes of potassium permanganate in 1 liter of distilled water, evaporate to about 750 c.c. to drive off the ammonia present, and make up to 1 liter again with ammonia-free water. To make ammonia-free water, add about 1 gramme of sodium carbonate to 1 liter of distilled water and boil until about one-fourth is evaporated. (3) Nessler's reagent: dissolve 1.5 grammes of potassium iodide in 10 c.c. of distilled water and 1.7 grammes of mercuric chloride ($HgCl_2$) in 30 c.c. of distilled water; add the mercuric chloride solution to the potassium iodide until a permanent precipitate is formed, and then dilute to 100 c.c. with a 20 per cent. solution of sodium hydrate, add the mercuric chloride solution until a permanent precipitate again forms, and allow to stand until clear; this reagent gives a brown or yellowish-brown coloration if ammonia be present in water, and improves on keeping.

Process.—Place in a retort 500 c.c. of the water to be examined, connect with a condenser, and boil gently so that the water may distil over slowly. The retort and condenser should have been thoroughly rinsed with

[1] Bergey's Hand-book of Practical Hygiene, p. 95.

ammonia-free water. Collect the distillate, 50 c.c. at a time, in Nessler tubes matched as to caliber, add 2 c.c. of Nessler's reagent to each 50 c.c., and determine the amount of ammonia or nitrogen in each as follows: Place in another Nessler tube of the same caliber a little less than 50 c.c. of ammonia-free water and 2 c.c. of Nessler's reagent, run in from a burette the dilute standard ammonium chloride solution until the color exactly matches that of the first 50 c.c. of the distillate, taking care to bring

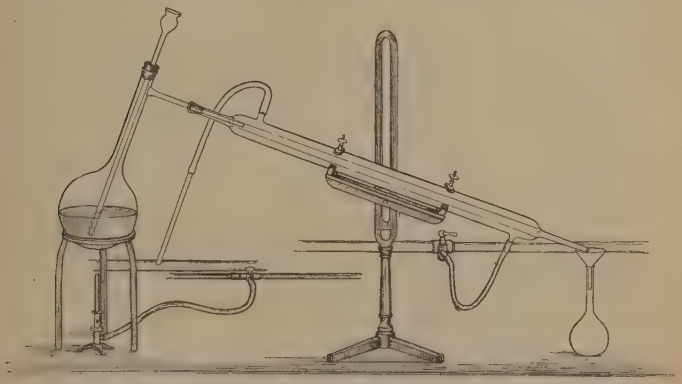

FIG. 150.—Distilling apparatus used in determining the ammonias in water. (Harrington.)

the fluid to the same level in the two tubes by the addition of ammonia-free water to one or the other. Repeat the process for each 50 c.c. of distillate until the test shows no more ammonia is coming over from the retort. The total amount of (dilute) ammonium chloride solution used indicates the total amount of nitrogen of the *free ammonia*. Usually all the free ammonia will come over in the first 150 or 200 c.c. of distillate. Compare the colors by looking down through the tubes on a white surface. Some waters yield so much ammonia in the first 50 c.c. of distillate that

a precipitate is formed upon the addition of the Nessler reagent. In such case the process should be repeated with a new 500 c.c. of the water to be examined and one-half or even lesser fraction of the first 50 c.c. distilled should be taken and diluted to that volume with ammonia-free water before adding the reagent. Or all of the distillates may be mixed together, 50 c.c. of this mixture taken, treated with the reagent and its content of ammonia determined by matching its color against that produced in another tube by the standard ammonium chloride solution used as above. This result must, of course, be multiplied by the proper multiple to indicate the amount of free ammonia in the total distillate. The free ammonia being determined, allow the retort to cool and add to the water remaining in it 50 c.c. of the alkaline permanganate solution. This, when heated, converts a certain proportion of the nitrogenous organic matter of the water into ammonia. Distil as before, estimating the amount of nitrogen in each 50 c.c. of the distillate until ammonia ceases to come over. The amount of ammonium chloride solution thus used will indicate the nitrogen of *albuminoid ammonia*, and the total amount of ammonium chloride solution used in the whole process gives the nitrogen of the total free and albuminoid ammonia in one-half liter of water.

Test for Hardness.—*Solutions required:* (1) Soap solution: dissolve 10 grammes of old, dry castile soap, free from sodium carbonate and hydrate, in 1 liter of weak (60 per cent.) alcohol. (2) Standard lime solution: dissolve 1.11 grammes of chemically pure calcium chloride in 1 liter of distilled water: 1 c.c. of this solution is equivalent to 1 mg. of calcium carbonate.

Process.—Ascertain how much soap solution is required to make a standard lather with 100 c.c. of distilled water as follows: Place the water in a flask holding about 250 c.c., and run in the soap solution from a burette, a few drops at a time, corking and shaking the flask well after each addition; the lather should be made up of small bubbles, have a depth of at least one-fourth of an

inch and be permanent for at least two minutes. Then standardize the soap solution by diluting 5 c.c. of the standard lime solution to 100 c.c. with distilled water, and determine how many c.c. of the soap solution are required to make a permanent lather as above with it; this quantity, less the number of c.c. needed to make a lather with 100 c.c. of distilled water, represents the amount of soap solution that will neutralize 5 mg. of calcium carbonate or its equivalent. Lastly, determine in the same way the number of c.c. of soap solution necessary to make a permanent lather with 100 c.c. of the water to be examined; again subtract the quantity of soap solution requisite to make a lather with 100 c.c. of distilled water, and estimate the amount of calcium carbonate or its equivalent present, as follows—*e. g.*, it takes 2 c.c. of soap solution to make a lather with the distilled water, and 12 c.c. with the diluted standard lime solution; then 12 c.c. $-$ 2 c.c. $=$ 10 c.c., which is equivalent to 5 c.c. of the standard lime solution, and accordingly each c.c. of the soap solution is equivalent to 0.5 c.c. of the standard lime solution, or to 0.5 mg. of calcium carbonate; consequently, if 100 c.c. of the water examined require 17 c.c. of soap solution, it must contain $(17-2) \times 0.5 = 7.5$ mg. of calcium carbonate or its equivalent, or 75 mg. to the liter. This test is not exactly accurate, since there is a gradual lessening in the amount of soap solution needed as the amount of lime increases. A better method, if time permits, is to dilute from 1 to 10 c.c. of the standard calcium chloride solution successively to 100 c.c., testing each dilution with the soap solution as above and thus making a scale to which the amount of soap solution needed for the sample water may be referred. If the sample water shows a hardness greater than that indicated by 10 c.c. of the standard calcium chloride solution, a fractional part of 100 c.c. of the water may be diluted up to that amount with distilled water and the test repeated, making a proper calculation later for the amount used.

Tests for Lead, Copper, and Iron.—To 50 or 100 c.c. of water in a white porcelain dish, or in a tall glass jar over white paper, add a few drops of ammonium sulphide; a dark coloration or precipitate indicates the presence of either lead, copper, or iron, due to formation of their respective sulphides. If only small quantities of one or more of the metals are present, it may be necessary to concentrate the water by boiling in order to secure the reaction. It should be remembered that the ammonium sulphide gives some color and that the later addition of acid may also cause some turbidity. Then add a few drops of hydrochloric acid: if the color disappears, iron only is present; if it persists, lead or copper is present. In the latter case add a few drops of acetic acid and about 1 c.c. of a *strong* solution of potassium cyanide: if the color disappears, it is due to copper; if it persists, it is due to lead. If lead only is present, the above test should detect one-tenth of a grain per gallon. The above tests may be corroborated as follows: Partly fill two test-tubes with the original water. To one add a little potassium chromate solution: a turbidity and the deepening of the color to canary-yellow indicate lead. Harvey claims that 0.3 milligramme of lead in 1 liter of water "will show a turbidity from chromate when 250 c.c. are treated with 0.1 gramme of potassium bichromate, and that in twelve hours the precipitate will settle and become still more distinct."[1] To the second test-tube add a drop of hydrochloric acid and a few drops of potassium ferrocyanide solution: a blue color indicates iron, in either the ferrous or ferric form; a bronze or mahogany-red color indicates copper.

Quantitative tests for the above metals may be made by making standard solutions of the respective elements or some of their salts, treating a measured quantity of the original water with the proper reagent as indicated above, and comparing the color produced with that given by a definite quantity of the respective standard solution.

[1] Harrington, loc. cit., p. 469.

Test for Phosphates.—*Solutions required:* Ammonium molybdate: dissolve 10 grammes of molybdic anhydride in 41.7 c.c. of ammonia (sp. gr., 0.96) and pour slowly into 125 c.c. of nitric acid (sp. gr., 1.20); allow to stand in a warm place for several days until clear.

Process.—Slightly acidulate 500 c.c. of water with nitric acid, evaporate to 50 c.c., and add a few drops of ferric chloride and ammonia to slight excess; filter, dissolve the precipitate in the smallest possible quantity of nitric acid and evaporate to 5 c.c.; heat nearly to boiling, add 20 c.c. of ammonium molybdate solution; keep the solution warm for one-half hour. If there is an appreciable quantity of precipitate, collect it on a small, weighed filter-paper, wash with distilled water, dry at 100° F., and weigh. The weight of the precipitate multiplied by 0.05 gives the amount of phosphorus tetroxide (PO_4) in the 500 c.c. of water.

The importance and relative value of the results of the foregoing tests in determining the purity or safety of a drinking-water, have been given in Chapter V on pages 225 to 228, inclusive.

FOOD.

Milk. — *Good Milk.* — Characteristics: ivory white, opaque, neutral or slightly alkaline reaction, no sediment, no unusual or offensive taste or odor, specific gravity, 1.029 or above; cream, 10 to 40 per cent. by volume; fats, 3 per cent. or more; total solids, 12.5 per cent. or more.

Water is indicated by low specific gravity and by low percentage of cream.

Skimming is indicated by a slightly raised specific gravity (2°), by a low percentage of cream, and by a poor color, though the deterioration in color may be disguised by the addition of annatto, etc.

Watering *and* skimming are indicated by lowered specific gravity, by low percentage of cream, and by poor color.

The specific gravity is determined by the lactometer, or lactodensimeter, in using which correction must be made for temperature, provided the latter varies much from 60° F., the standard.

The percentage of cream is determined by the cream gauge or creamometer; the milk should be allowed to stand in the creamometer for at least eight to ten hours, and should be covered.

A very high percentage of cream tends to lower the specific gravity theoretically; but when a milk is rich in fat it is also rich in solids not fat.

An acid reaction, unless very slight, indicates souring of the milk or the addition of some preserving acid. A strongly alkaline reaction indicates the addition of some substance like chalk, sodium carbonate, etc., to increase the specific gravity. Such addition is verified by an excess of total solids, and by the effervescence of the latter —after drying—upon the addition of a drop or two of hydrochloric acid.

To determine the percentage of total solids: Weigh a small evaporating dish, preferably platinum, add 5 to 10 c.c. of milk, and weigh dish and milk to get weight of milk; evaporate to dryness over a water-bath, completing the drying in a water-oven until there is no further loss of weight; weigh dish and contents (total solids); subtract weight of dish, multiply by 100, and divide by weight of milk. Result: the percentage of total solids.

To determine the percentage of ash: Ignite the total solids over a naked flame until all black specks have disappeared; cool and weigh; multiply weight of ash by 100, and divide by weight of milk. Result: percentage of ash.

To determine the percentage of fats: Proceed as above with 10 c.c. of milk, and evaporate until the residue is a tenacious pulp, extinguish the flame, fill the dish half-full of ether, stir and triturate the residue thoroughly with a glass rod, decant the ether and filter it through a small filter-paper, reserving the filtrate; add more ether to the

residue, stir and triturate as before, and filter, repeating the process three times or until the residue is perfectly

FIG. 151.—Lactodensimeter. (Harrington.)

FIG. 152.—Bottle for determining percentage of fat by means of the centrifuge.

white; wash the filter-paper well with ether, collect the latter and add to the preceding filtrate; evaporate the ether filtrate until only the fat remains and its weight is

constant; weigh the fat, multiply by 100, and divide by the weight of the milk. Result: percentage of fat.

This method when carefully performed is said to be fully as accurate as the extraction (Soxhlet) method, and does not require the more expensive apparatus of the latter. If the residue from which the fat has been exhausted is carefully dried on a water-bath at 100° C. until there is no further loss by evaporation, its weight will be that of the "solids not fat" of the milk.

Centrifugal method: Where a centrifuge is available for use, the following method for the fat-determination will be found to give results that are probably accurate to within 0.2 per cent. of fat:

Two solutions are necessary: (1) Fusel oil, 37 c.c.; wood or methyl alcohol, 13 c.c.; hydrochloric acid, 50 c.c. (2) Sulphuric acid, sp. gr., 1.83.

Into the milk bottle (Fig. 152), which is made to fit the centrifuge and which has a long, graduated neck, 5 c.c. of the milk to be examined are introduced by means of a pipette, and to this 1 c.c. of the alcohol solution (1) is added and the mixture well shaken by hand. The sulphuric acid is then added, little by little, with frequent shaking, until the bottle is filled to the topmost (zero) graduation. It is then rapidly whirled in the centrifuge until only the fat occupies the neck as a clear layer, when the actual percentage can be read from the graduations. When the milk is very rich—*i. e.*, containing more than 5 per cent. of fat—it will be necessary to dilute the milk with an equal volume of water, and then to multiply the result by 2. Likewise, cream should be diluted with 4 parts of water and the result multiplied by 5. The same principle is employed in the Babcock and other cream-testers now largely used by dairymen, etc.

A somewhat simpler method has been devised by Prof. Meeker, in which the only reagent is sulphuric acid, sp. gr. 1.83, and a tube of different form (Fig. 153) is used. Into this tube the milk is introduced from a pipette holding exactly 8.8 c.c., and having a long delivery

end to carry the milk beyond the constricted and graduated portion. The sulphuric acid is then added in equal

FIG. 153.—Meeker tube for testing milk in centrifuge.

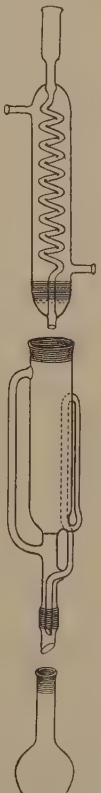

FIG. 154.—Soxhlet extraction apparatus. (Harrington.)

volume, filling the tube to the zero mark, after which the stopper is inserted and the milk and acid thoroughly mixed by inverting and reinverting the tube. This breaks up the casein of the milk and frees the fat, which will collect in the graduated part when the tube is whirled in the centrifuge. Owing to cooling, there may be a slight contraction of the liquid, and the top may be slightly below the zero mark, so it is well to again warm the milk by immersing the tube in hot water, and to give a second whirling for but a moment or two. The percentage of fat is indicated by the difference of the reading of its upper and lower limits.

The extraction method:[1] "About 10 grammes of milk are carefully weighed in a glass or porcelain capsule and mixed with about 10 grammes of freshly ignited sand, pumice-stone, or asbestos, and evaporated to dryness on a water-bath. The dish with its contents is then finely pulverized and transferred to a Soxhlet extraction apparatus and the fat extracted with ether for at least five hours. The ether extract of the fat is then evaporated to dryness on a water-bath and the residue dried to constant weight (at 100° C.) and weighed. The increased weight of the flask (of the Soxhlet apparatus) will represent the fat in the 10 grammes of milk."

A Soxhlet apparatus is so constructed that a quantity of ether is repeatedly evaporated and condensed in it without loss, the condensed ether being made to percolate through substances placed in the upper part of the apparatus and to extract therefrom soluble matters, such as fat, which are collected in a small flask below, and from which the ether can finally be evaporated.

Test for annatto: A percentage of cream considerably lower than the color of the milk would indicate justifies the suspicion that some coloring-matter has been used. This is frequently annatto.

"To about 100 c.c. of milk in a cylinder add a few cubic

[1] Bergey's Hand-book of Practical Hygiene, p. 129.

centimeters of sodium carbonate solution to insure a strongly alkaline reaction during the examination, and then introduce a strip of heavy white filter-paper about 0.5 by 5.5 inches, and set the whole away in a dark place over night. If any annatto color is present, it will, through selective affinity, pass from the milk to the fiber of the paper, which thereby acquires a salmon tint, the depth of which is dependent, naturally, upon the amount of substance present. The strip is withdrawn from the milk, washed gently in running water, and laid upon a piece of paper of the same kind as itself. If so much as 1 part of the annatto solution in 100,000 is present, the strip will show a distinct salmon tint. On dipping the strip into stannous chloride solution the color is changed to pink."[1]

Test for boric acid: Upon igniting the total solids, boric acid or boron gives a greenish tinge to flame. Place in a porcelain dish 5 c.c. of milk, 1 drop of strong hydrochloric acid, and 2 drops of a saturated tincture of turmeric. Dry on a water-bath, remove as soon as dry; cool, and add 1 drop of ammonia on a glass rod. A slaty-blue color, changing to green, is given if borax is present. This test will show $\frac{1}{1000}$ grain of borax. Less will give the green color, but not the blue.

Test for salicylic acid and salicylates (Bergey): Dilute the milk (100 c.c.) with an equal bulk of distilled water at 60° C.; precipitate with 8 drops of acetic acid and 8 drops of a solution of mercuric oxide in nitric acid; shake and filter. To the filtrate add 50 c.c. of ether, which takes up the salicylic acid; decant, and filter the supernatant ether. Evaporate this filtrate nearly to dryness, and add a few drops of highly diluted neutral ferric chloride. A violet color indicates the presence of salicylic acid, the depth of color increasing with the amount.

To test for salicylic acid in butter, it is first treated with sodium carbonate and the homogeneous mixture

[1] Harrington, Practical Hygiene, 5th ed., p. 168.

acidulated with sulphuric acid, and then shaken with a mixture of equal parts of ether and petroleum ether, after which the supernatant ether is filtered off and treated as above.

Test for formaldehyde (Bergey): Add an equal volume of water to the milk or butter to be tested, place in a flask on a steam-bath and distil over about one-fourth the total volume. Treat 10 c.c. of the distillate with 2 drops of ammoniacal silver solution (made by dissolving 1 gramme of silver nitrate in 30 c.c. of distilled water and adding ammonia until the precipitate that first appears is redissolved, then diluting to 50 c.c. with water). If formaldehyde is present, it causes a black cloud in the distillate after standing for several hours in the dark.

Harrington gives the following test among others: "Mix in a porcelain dish 10 c.c. each of milk and hydrochloric acid (sp. gr., 1.2) and 1 drop of ferric chloride solution. Heat and stir vigorously. If formalin has been added, a violet color will appear before the boiling-point has been reached, varying in intensity according to the amount present. This process is exceedingly delicate and will detect 1 part in 500,000 in the fresh condition."[1]

According to Hehner, "no formaldehyde could be detected at the end of a week in a sample (of milk) to which had been added 1 part in 100,000; after two weeks none could be detected in a sample of 1 part in 50,000; and after three weeks only a faint trace could be detected in a sample of 1 part in 25,000."[2]

Butter and Oleomargarine.—Pure butter should have good taste, odor, and color; it should not be rancid, and should not contain too much water or salt, nor should it have any added coloring-matter. The average composition should be about as follows: fat, 82 per cent.; casein, 2 per cent. (not over 3 per cent.); ash or salts, 2 per

[1] For other tests for formaldehyde see Harrington, 5th ed., pp. 170 and 171; and Leffmann and Bevan's Food Analysis, pp. 220-222.

[2] Leffmann and Bevan, loc. cit.

cent.; water, 13 per cent. Butter-fat is a compound of glycerin with certain fatty acids, some of them volatile and soluble in hot water, others non-volatile and insoluble in hot water.

Oleomargarine consists of ordinary animal or vegetable-fats, melted, strained, cooled with ice, worked up with milk, colored, and salted. The fats are usually beef or mutton-fat, lard, or cotton-seed, palm, or cocoanut oil. If care and cleanliness are observed in the manufacture, oleomargarine is not harmful nor innutritious, but it should not be sold as butter.

Fraud is to be detected by observing the difference in composition and properties of the *fats*. For instance:

BUTTER-FAT.	BEEF-FAT, ETC.
1. The specific gravity is very rarely below 910, never below 909.8.	1. Beef-fat, etc., is never above 904.5.
2. The soluble, volatile fatty acids average between 6 and 7 per cent., never below 4.5 per cent.	2. Rarely more than 0.5 per cent., never above 0.75 per cent.
3. The insoluble fatty acids form about 88 per cent. of the total weight of butter fat.	3. Generally about 95 per cent.
4. The melting-point of the fat varies from 86° to 94° F.; is usually from 88° to 90° F.	4. Rarely, if ever, above 82° F.
5. Is readily and completely soluble in ether.	5. Less so, and leaves a residue.
6. Under the microscope pure butter-fat consists of a collection of small oil globules, with an occasional large one.	6. The contours of the small oil globules are less distinct, and the larger ones are more numerous and irregular in size.
7. No crystals, except when the fat has been melted.	7. Crystals of the non-volatile acids are often seen.

To determine the specific gravity of butter-fat: Melt a quantity of the butter in a beaker in a water-bath at about 150° F. When the fat is perfectly clear and transparent, carefully decant the fat from the lower stratum of water, curd, and salt into a fine filter; collect the filtrate and pour into a specific gravity bottle, which has been previously weighed, both when empty and when

filled with distilled water at 100° F. See that the bottle is exactly full of the fat, wipe clean, and weigh when the temperature is as near 100° F. as possible, because solidification soon begins below this temperature. Subtract the weight of the bottle, divide by the weight of the water which the bottle will hold, and multiply by 1000; the result is the specific gravity.

To find the melting-point: Pour a little melted fat into a small test-tube (2″ x $\frac{1}{4}$″) and cool. Partly fill two beakers of unequal size with cold water; place the test-tube in the smaller (taking care to allow no water to mix with the fat), and the smaller in the larger, and gently heat the outer beaker. Suspend a thermometer in the smaller, near the test-tube, and note the temperature when the fat *begins* to melt; this is the melting-point.

To determine the percentage of insoluble (non-volatile) fatty acids: To 6 grammes of butter-fat add 50 c.c. of alcohol containing 2 grammes of caustic potash (KHO) and boil gently for fifteen or twenty minutes to saponify the fat. Dissolve the soaps thus formed in 150 to 200 c.c. of water, and decompose with about 25 c.c. of dilute hydrochloric acid. The separated fatty acids are poured upon a weighed filter-paper, washed with 2 liters of boiling water, dried at 95° to 98° C., and then weighed. The weight of these insoluble fatty acids should not be over 90 per cent. of the weight of the butter fat.

Flour and Bread.—*Wheat Flour.*—Characteristics: almost perfectly white, smooth and free from grit; no mouldy or unpleasant odor; cohesive when lightly compressed; no signs of parasites under the microscope; water less than 18 per cent.; ash less than 2 per cent.

"The roller process yields a slightly rough flour, and the hard winter wheat may give a yellowish tinge. Good flour is slightly acid to test-paper, but not to the taste, and an acidity that may be recognized by the senses means a change. Acid flour means sour bread, and any disagreeable taste or odor indicates bad flour. When boiling

water is poured on a little flour, there should arise no odor but that of freshly ground wheat."[1]

To determine the percentage of water and ash: In a weighed platinum (or porcelain) dish place about 50 grammes of flour, weigh, and dry over a water-bath for an hour or so; then complete the evaporation in a water-oven until there is no further loss of weight; weigh, subtract this weight, less the weight of the dish, from the original weight of the flour. Multiply the remainder by 100 and divide by the original weight of the flour. The result is the percentage of water. Then ignite the dried flour in the dish and incinerate until there are no longer any black particles and only the ash remains; cool, weigh, subtract weight of dish, multiply the remainder by 100, and divide by the original weight of the flour. The result is the percentage of ash.

To determine the percentage of gluten: By means of a glass rod mix a weighed quantity of flour with a *little* distilled water into a stiff dough; then repeatedly wash away the starch and soluble constituents, kneading the dough with the rod or fingers, and continuing until the wash-water comes away clear; the gluten and a small amount of fat and salt remain. Spread on a weighed dish or crucible lid, dry in a water-oven, and weigh; multiply by 100 and divide by the original weight of the flour. The result is the *approximate* percentage of gluten. The gluten should pull out into long threads; otherwise, it is poor.

"The relative strength and elasticity of the gluten, which are determined comparatively by manipulating a small quantity of flour intimately mixed with half its weight of water, make a standard for comparison. This is known as the dough-test, and its failure shows weak flour, from poor wheat or imperfect milling and defective gluten."[2]

An excess of water impairs the keeping quality and

[1] Colonel A. A. Woodhull, M.D., article on "Military Hygiene," in The Reference Hand-book of the Medical Sciences.

[2] Colonel A. A. Woodhull, M.D., loc. cit.

lessens the amount of nutriment in the flour. An excess of ash indicates the addition of mineral substances. A deficiency of gluten may also indicate that the flour is not pure wheat flour. Parasites and fungi are especially likely to be found in old, damp, or inferior flour.

To test for mineral substances: Shake a little flour in a test-tube with some chloroform, and allow it to stand for a few minutes. The flour floats and any mineral matter sinks to the bottom, when it can be removed with a pipette and examined under a microscope.

Wheat Bread.—Characteristics: fairly dry, light, and spongy; clean and nearly white; of pleasant taste; not sodden, acid, or musty; ash not over 3 per cent.; no parasites or mouldiness; no flour other than wheat; but little, if any, alum; no copper sulphate.

Test for alum: Add 5 c.c. of a 5 per cent. tincture of logwood and 5 c.c. of a 15 per cent. solution of ammonium carbonate to 25 c.c. of water; soak a crumb of the bread in this for a few minutes; drain and gently dry; alum is indicated by a violet or lavender color; its absence by a dirty brown color on drying.

For further tests and details in work pertaining to a laboratory of hygiene the reader is referred to Fox's Examination of Food, Air, and Water; Kenwood's Hygienic Laboratory; Bergey's Hand-book of Practical Hygiene; Harrington's Practical Hygiene; Leffmann and Bevan's Food Analysis; Standard Methods of Water Analysis of the American Public Health Association; Thresh's Simple Method of Water Analysis. In the latter the author has devised a series of tests requiring the simplest possible apparatus and a group of solid reagents which can be prepared in tabloid form, each piece containing exactly the quantity required for the respective test. The entire outfit, which can be had of Burroughs, Wellcome & Co. or their agents, can be packed in comparatively small space and is easily transported from place to place, thus enabling the investigator to make his tests at or near the source of supply.

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